

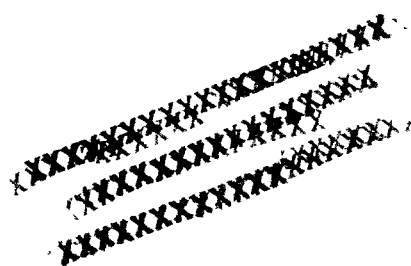
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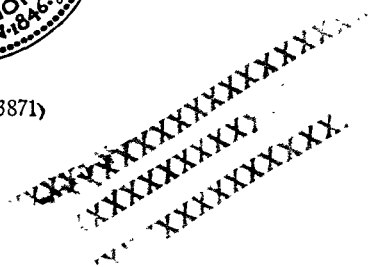
ANNUAL REPORT OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION

SHOWING THE
OPERATIONS, EXPENDITURES, AND
CONDITION OF THE INSTITUTION
FOR THE YEAR ENDED JUNE 30

1946



(Publication 3871)



UNITED STATES
GOVERNMENT PRINTING OFFICE
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LETTER OF TRANSMITTAL

SMITHSONIAN INSTITUTION,
Washington, December 12, 1946.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ended June 30, 1946. I have the honor to be,

Respectfully,

A. WETMORE, *Secretary.*

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THE SMITHSONIAN INSTITUTION

June 30, 1946

Presiding Officer ex officio.—HARRY S. TRUMAN, President of the United States.
Chancellor.—[Vacant].

Members of the Institution:

HARRY S. TRUMAN, President of the United States.
—— Vice President of the United States.
FRED M. VINSON, Chief Justice of the United States.
JAMES F. BYRNES, Secretary of State.
JOHN W. SNYDER, Secretary of the Treasury.
ROBERT P. PATTERSON, Secretary of War.
TOM C. CLARK, Attorney General.
FRANK C. WALKER, Postmaster General.
JAMES V. FORRESTAL, Secretary of the Navy.
JULIUS A. KRUG, Secretary of the Interior.
CLINTON P. ANDERSON, Secretary of Agriculture.
HENRY A. WALLACE, Secretary of Commerce.
LEWIS B. SCHWELLENBACH, Secretary of Labor.

Regents of the Institution:

FRED M. VINSON, Chief Justice of the United States.
—— Vice President of the United States.
ALBEN W. BARKLEY, Member of the Senate.
WALLACE H. WHITE, Jr., Member of the Senate.
WALTER F. GEORGE, Member of the Senate.
CLARENCE CANNON, Member of the House of Representatives.
EDWARD E. COX, Member of the House of Representatives.
B. CARROLL REECE, Member of the House of Representatives.
FREDERIC A. DELANO, citizen of Washington, D. C.
HARVEY N. DAVIS, citizen of New Jersey.
ARTHUR H. COMPTON, citizen of Missouri.
VANNEVAR BUSH, citizen of Washington, D. C.
FREDERIC C. WALCOTT, citizen of Connecticut.

Executive Committee.—FREDERIC A. DELANO, VANNEVAR BUSH, CLARENCE CANNON.

Secretary.—ALEXANDER WETMORE.

Assistant Secretary.—JOHN E. GRAF.

Administrative assistant to the Secretary.—HARRY W. DORSEY.

Treasurer.—NICHOLAS W. DORSEY.

Chief, editorial division.—WEBSTER P. TRUE.

Administrative accountant.—THOMAS F. CLARK.

Librarian.—LEILA F. CLARK.

Personnel officer.—B. T. CAWWITHEN.

Purchasing officer.—ANTHONY W. WILDING.

UNITED STATES NATIONAL MUSEUM

Director.—ALEXANDER WETMORE.

SCIENTIFIC STAFF

DEPARTMENT OF ANTHROPOLOGY:

Frank M. Setzler, head curator; A. J. Andrews, chief preparator.

Division of Archeology: Neil M. Judd, curator; Waldo R. Wedel, associate curator; J. R. Caldwell, scientific aid; J. Townsend Russell, honorary assistant curator of Old World archeology.

Division of Ethnology: H. W. Krieger, curator; J. O. Ewers, associate curator; R. A. Elder, Jr., assistant curator; Arthur P. Rice, collaborator.

Division of Physical Anthropology: T. Dale Stewart, curator; M. T. Newman, associate curator.

Collaborator in anthropology: George Grant MacCurdy.

DEPARTMENT OF BIOLOGY:

Waldo L. Schmitt, head curator; W. L. Brown, chief taxidermist; Aime M. Awl, illustrator.

Division of Mammals: Remington Kellogg, curator; D. H. Johnson, associate curator*; R. M. Gilmore, associate curator; H. Harold Shamel, scientific aid; A. Brazier Howell, collaborator; Gerrit S. Miller, Jr., associate.

Division of Birds: Herbert Friedmann, curator; H. G. Deignan, associate curator; Alexander Wetmore, custodian of alcoholic and skeleton collections; Arthur C. Bent, collaborator.

Division of Reptiles and Batrachians: Doris M. Cochran, associate curator.

Division of Fishes: Leonard P. Schultz, curator; R. R. Miller, associate curator.

Division of Insects: L. O. Howard, honorary curator; Edward A. Chapin, curator; R. E. Blackwelder, associate curator; W. E. Hoffmann, associate curator; W. L. Jellison, collaborator.

Section of Hymenoptera: S. A. Rohwer, custodian; W. M. Mann, assistant custodian; Robert A. Cushman, assistant custodian.

Section of Myriapoda: O. F. Cook, custodian.

Section of Diptera: Charles T. Greene, assistant custodian.

Section of Coleoptera: L. L. Buchanan, specialist for Casey collection.

Section of Lepidoptera: J. T. Barnes, collaborator.

Section of Forest Tree Beetles: A. D. Hopkins, custodian.

Division of Marine Invertebrates: Waldo L. Schmitt, curator; Mrs. Harriet Richardson Searle, collaborator; Max M. Ellis, collaborator; J. Percy Moore, collaborator; Joseph A. Cushman, collaborator in Foraminifera; Mrs. M. S. Wilson, collaborator in copepod Crustacea.

Division of Mollusks: Harald A. Rehder, associate curator; Joseph P. E. Morrison, assistant curator.

Associate, Division of Mollusks: P. Bartsch.

Section of Helminthological Collections: Benjamin Schwartz, collaborator.

Division of Echinoderms: Austin H. Clark, curator.

*Now on war duty.

DEPARTMENT OF BIOLOGY—Continued

Division of Plants (National Herbarium): E. P. Killip, curator; Emery C. Leonard, assistant curator; Conrad V. Morton, assistant curator; Egbert H. Walker, assistant curator; John A. Stevenson, custodian of C. G. Lloyd mycological collection.

Associate in Botany: W. R. Maxon.

Section of Grasses: Agnes Chase, custodian.

Section of Cryptogamic Collections: O. F. Cook, assistant curator.

Section of Higher Algae: W. T. Swingle, custodian.

Section of Lower Fungi: D. G. Fairchild, custodian.

Section of Diatoms: Paul S. Conger, associate curator.

Associates in Zoology: Theodore S. Palmer, William B. Marshall, A. G. Böving, W. K. Fisher, C. R. Shoemaker, E. A. Goldman.

Associates in Botany: Henri Pittier, F. A. McClure.

Collaborator in Zoology: Robert Sterling Clark.

Collaborators in Biology: A. K. Fisher, David C. Graham.

DEPARTMENT OF GEOLOGY:

R. S. Bassler, head curator; Jessie G. Beach, aid.

Division of Mineralogy and Petrology: W. F. Foshag, curator; E. P. Henderson, associate curator; B. O. Reberholt, scientific aid; Frank L. Hess, custodian of rare metals and rare earths.

Division of Invertebrate Paleontology and Paleobotany: Gustav A. Cooper, curator; A. R. Loeblich, Jr., associate curator; J. Brookes Knight, research associate in Paleontology.

Section of Invertebrate Paleontology: T. W. Stanton, custodian of Mesozoic collection; J. B. Reeside, Jr., custodian of Mesozoic collection;

Paul Bartsch, curator of Cenozoic collection.

Division of Vertebrate Paleontology: C. L. Gazin, curator; Norman H. Boss, chief preparator; A. C. Murray, scientific aid.

Associates in Mineralogy: W. T. Schaller, S. H. Perry.

Associate in Paleontology: T. W. Vaughan.

Associate in Petrology: Whitman Cross.

DEPARTMENT OF ENGINEERING AND INDUSTRIES:

Carl W. Mitman, head curator.

Division of Engineering: Frank A. Taylor, curator.

Section of Transportation and Civil Engineering: Frank A. Taylor, in charge.

Section of Aeronautics: Paul E. Garber,* associate curator, F. C. Reed, acting associate curator.

Section of Mechanical Engineering: Frank A. Taylor, in charge.

Section of Electrical Engineering and Communications: Frank A. Taylor, in charge.

Section of Mining and Metallurgical Engineering: Carl W. Mitman, in charge.

Section of Physical Sciences and Measurement: Frank A. Taylor, in charge.

Section of Tools: Frank A. Taylor, in charge.

*Now on war duty.

VIII ANNUAL REPORT SMITHSONIAN INSTITUTION, 1946

DEPARTMENT OF ENGINEERING AND INDUSTRIES—Continued

Division of Crafts and Industries: Frederick L. Lewton, curator; Elizabeth W. Rosson, assistant curator.

Section of Textiles: Frederick L. Lewton, in charge.

Section of Woods and Wood Technology: William N. Watkins, associate curator.

Section of Chemical Industries: Frederick L. Lewton, in charge.

Section of Agricultural Industries: Frederick L. Lewton, in charge.

Division of Medicine and Public Health: Charles Whitebread, associate curator.

Division of Graphic Arts: R. P. Tolman, curator.

Section of Photography: A. J. Olmsted, associate curator.

DIVISION OF HISTORY: T. T. Belote, curator; Charles Carey, associate curator; J. Russell Sirlouis, scientific aid; Catherine L. Manning, assistant curator (philately).

ADMINISTRATIVE STAFF

Chief of correspondence and documents.—H. S. BRYANT.

Assistant chief of correspondence and documents.—L. E. COMMERFORD.

Superintendent of buildings and labor.—L. L. OLIVER.

Assistant superintendent of buildings and labor.—CHARLES C. SINCLAIR.

Editor.—PAUL H. OEHSE.

Accountant and auditor.—T. F. CLARK.

Photographer.—G. I. HIGHTOWER.

Property officer.—A. W. WILDING.

Assistant librarian.—ELISABETH H. GAZIN.

NATIONAL GALLERY OF ART

Trustees:

FRED M. VINSON, Chief Justice of the United States, *Chairman*.

JAMES F. BYRNES, Secretary of State.

JOHN W. SNYDER, Secretary of the Treasury.

ALEXANDER WETMORE, Secretary of the Smithsonian Institution.

PAUL MELLON.

FERDINAND LAMMOT BELIN.

DUNCAN PHILLIPS.

SAMUEL H. KRESS.

CHESTER DALE.

President.—SAMUEL H. KRESS.

Vice President.—FERDINAND LAMMOT BELIN.

Secretary-Treasurer.—HUNTINGTON CAIRNS.

Director.—DAVID E. FINLEY.

Administrator.—H. A. MCBRIDE.

General Counsel.—HUNTINGTON CAIRNS.

Chief Curator.—JOHN WALKER.

Assistant Director.—MACGILL JAMES.

NATIONAL COLLECTION OF FINE ARTS

Acting Director.—RUEL P. TOLMAN.

FREER GALLERY OF ART

Director.—A. G. WENLEY.

Assistant Director.—GRACE DUNHAM GUEST.

Associate in research.—J. A. POPE.

Associate in Near Eastern art.—RICHARD ETTINGHAUSEN.

BUREAU OF AMERICAN ETHNOLOGY

Chief.—MATTHEW W. STIRLING.

Assistant Chief.—FRANK H. H. ROBERTS, Jr.

Senior ethnologists.—H. B. COLLINS, Jr., JOHN P. HARRINGTON, W. N. FENTON.

Senior anthropologists.—H. G. BARNETT, G. R. WILLEY.

Collaborator.—JOHN R. SWANTON.

Editor.—M. HELEN PALMER.

Librarian.—MIRIAM B. KETCHUM.

Illustrator.—EDWIN G. CASSEDY.

INSTITUTE OF SOCIAL ANTHROPOLOGY.—JULIAN H. STEWARD, *Director.*

INTERNATIONAL EXCHANGE SERVICE

Acting Chief.—HARRY W. DORSEY.

Acting Chief Clerk.—D. G. WILLIAMS.

NATIONAL ZOOLOGICAL PARK

Director.—WILLIAM M. MANN.

Assistant Director.—ERNEST P. WALKER.

Head Keeper.—FRANK O. LOWE.

ASTROPHYSICAL OBSERVATORY

Director.—LOYAL B. ALDRICH.

DIVISION OF ASTROPHYSICAL RESEARCH: Loyal B. Aldrich, in charge; William H. Hoover, senior astrophysicist; Charles G. Abbot, research associate.

DIVISION OF RADIATION AND ORGANISMS: Earl S. Johnston, assistant director; Leland B. Clark, engineer (precision instruments); Robert L. Weintraub, associate biochemist; Leonard Price, junior physicist (biophysics).

REPORT OF THE SECRETARY OF THE SMITHSONIAN INSTITUTION

ALEXANDER WETMORE

FOR THE YEAR ENDED JUNE 30, 1946

To the Board of Regents of the Smithsonian Institution.

GENTLEMEN: I have the honor to submit herewith my report showing the activities and condition of the Smithsonian Institution and the Government bureaus under its administrative charge during the fiscal year ended June 30, 1946. The first 19 pages contain a summary account of the affairs of the Institution. Appendixes 1 to 10 give more detailed reports of the operations of the National Museum, the National Gallery of Art, the National Collection of Fine Arts, the Freer Gallery of Art, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, the Astrophysical Observatory, the Smithsonian library, and of the publications issued under the direction of the Institution. On page 129 is the financial report of the executive committee of the Board of Regents.

I regret to have to record here the death on April 22, 1946, of the Chancellor of the Institution, Chief Justice Harlan Fiske Stone. Chief Justice Stone was elected Chancellor by the Board of Regents on January 16, 1942, to succeed the former Chief Justice Charles Evans Hughes, and from the day of his appointment took a keen interest in the Institution's affairs. He had planned an active part in the Smithsonian Centennial celebration starting on August 10, 1946, and as Chancellor he took several steps to insure the effective functioning of the Institution in the years to come. His successor should be elected at the next meeting of the board.

THE ESTABLISHMENT

The Smithsonian Institution was created by act of Congress in 1846, according to the terms of the will of James Smithson, of England, who in 1826 bequeathed his property to the United States of America "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." In receiving the property and accepting the trust, Congress determined that the Federal Government was without authority to

administer the trust directly, and, therefore, constituted an "establishment" whose statutory members are "the President, the Vice President, the Chief Justice, and the heads of the executive departments."

THE BOARD OF REGENTS

During the year the following changes occurred in the personnel of the Board of Regents:

The lamented death of Chief Justice Harlan Fiske Stone, on April 22, 1946, created a vacancy in the office of Chancellor of the Board of Regents.

November 23, 1945. A vacancy in the class of citizen regents, caused by the death of Dr. Roland S. Morris, of Pennsylvania, has not yet been filled.

May 2, 1946. Dr. Vannevar Bush, citizen regent, was reappointed by joint resolution of Congress to succeed himself for a statutory term of 6 years.

June 24, 1946. The Honorable Fred M. Vinson, on his appointment as Chief Justice of the United States, became *ex officio* a member of the Board of Regents.

The roll of regents at the close of the fiscal year, June 30, 1946, was as follows:

Fred M. Vinson, Chief Justice of the United States; members from the Senate—Alben W. Barkley, Wallace H. White, Jr., Walter F. George; members from the House of Representatives—Clarence Cannon, Edward E. Cox, B. Carroll Reece; citizen members, Frederic A. Delano, Washington, D. C., Harvey N. Davis, New Jersey, Arthur H. Compton, Missouri, Vannevar Bush, Washington, D. C., and Frederic C. Walcott, Connecticut.

Proceedings.—The annual meeting of the Board of Regents was held on January 18, 1946, with the following members present: Chief Justice Harlan F. Stone, Chancellor; Senator Wallace H. White, Jr.; Representatives Edward E. Cox and B. Carroll Reece; citizen regents, Dr. Harvey N. Davis, Dr. Vannevar Bush, Frederic A. Delano, and Frederic C. Walcott; the Secretary, Dr. Alexander Wetmore, and the Assistant Secretary, John E. Graf. Dr. W. J. Robbins, chairman of the Committee on Future Policies, attended the opening of the meeting by invitation and later withdrew.

In accordance with the resolution passed by the Board at the last annual meeting, the Chancellor appointed the following to serve on the Committee on Future Policies of the Smithsonian Institution: Dr. William J. Robbins (chairman), New York Botanical Garden; Dr. L. P. Eisenhart, American Philosophical Society; Dr. George Gaylord Simpson, American Museum of Natural History; Dr. Zay

Jeffries, General Electric Co.; Dr. Walter S. Adams, Mount Wilson Observatory; Dr. F. R. Reichelderfer, United States Weather Bureau; and Dr. A. V. Kidder, Carnegie Institution of Washington. Dr. Robbins, chairman, stated that this committee would do its best to present an acceptable program for the future of the Institution, and announced that the first meeting would be held on January 30, 1946, in the Smithsonian Building.

The Secretary presented his annual report covering the activities of the parent institution and of its several branches, including the financial report of the executive committee, for the fiscal year ended June 30, 1945, which was accepted by the Board. The usual resolution authorizing the expenditure by the Secretary of the income of the Institution for the fiscal year ending June 30, 1947, was adopted by the Board.

The annual report of the Smithsonian Art Commission was presented by the Secretary and accepted by the Board. The Commission, at its meeting on December 4, 1945, accepted several works of art. A resolution was adopted to reelect the following members for 4-year terms: John Nicholas Brown, Mahonri M. Young, George Hewitt Myers, and Robert Woods Bliss. Vacancies on the Commission were caused by the death of Herbert Adams and the resignation of Edward W. Redfield. The names of John Taylor Arms and Eugene E. Speicher, recommended by the Commission, were approved by the Board to fill the above vacancies. Paul Manship was reelected chairman, and Dr. Wetmore was reelected Secretary.

Tentative plans were presented by the Secretary for the Centennial celebration to be held during August 1946.

The matter of the Secretary's salary and pension was referred to the executive committee with power to act.

The Secretary reported that Mrs. Charleyne Whitney Gellatly, widow of John Gellatly, had brought proceedings before the Court of Claims through a bill in Congress, demanding restitution or payment for certain objects in the Gellatly art collection. The Smithsonian Institution is defended in this proceeding by the Department of Justice, through Grover Sherrod, and has, in addition, the valuable assistance of Huntington Cairns, General Counsel for the National Gallery of Art. Hearing on the case was set for February 12, 1946.

By the terms of the will of Dr. Aleš Hrdlička, deceased member of the staff, a sum of money was bequeathed to the Smithsonian Institution for the benefit of educational establishments in Dr. Hrdlička's native town of Humpolec, Bohemia. Acceptance of this trust fund was approved by the Board. A further bequest in the Hrdlička will,

to provide for the reprinting of his papers on physical anthropology, was declined as being impracticable because of the inadequacy of the funds provided.

On December 20, 1938, Miss Annie-May Hegeman advised the Institution that, as a memorial to her father, Henry Kirke Porter, she had tendered to the Library of Congress Trust Fund Board conveyance of the property owned by her at the corner of Sixteenth and I Streets NW., in Washington, as a gift, under agreement that when the property was sold, the Library of Congress Trust Fund Board should pay one-half of the net proceeds of such sale to the Smithsonian Institution, to be invested, and the income thereof to be applied to the general purposes of the Institution, the gift to be recorded as "The Henry Kirke Porter Memorial Fund." The Secretary reported that the property had just been sold at a price of \$600,000; under the terms of the gift the Institution will receive one-half of the net proceeds.

At the last meeting the Board authorized the executive committee to have a survey made of the business methods and practices now in effect in the Institution to determine whether changes or improvements were required. The committee directed the Secretary on their behalf to enter into contract with the firm of Peat, Marwick, Mitchell & Co., who specialize in such work. This firm has rendered a comprehensive report covering organization and personnel, business methods, and accounting procedures, from which the Secretary gave the following quotation:

"Our conclusions in summary are that the administrative organization is set up along simple and effective lines, the personnel is of high caliber, conscientious and efficient for the particular requirements of the Institution, the business methods on the whole are very good, and the accounting system is essentially sound in principle. We have suggestions to offer for some changes toward improvements which we believe to be possible. These are given in the course of our comments in more detail upon the various topics falling within this area."

In a special statement, Dr. Wetmore outlined to the Board recent activities carried on by all branches of the Institution.

FINANCES

A statement on finances will be found in the report of the executive committee of the Board of Regents, page 129.

SMITHSONIAN CENTENNIAL

The year 1946 marks the one-hundredth year since the founding of the Institution. Strictly speaking, this report covers only the fiscal year ended June 30, 1946, but as the actual anniversary of the estab-

lishment of the Institution falls on August 10, only a little over a month after the beginning of the new fiscal year, it seems advisable in this report to anticipate to the extent of describing the Centennial observances.

Smithsonian commemorative stamp.—Among the outstanding honors that came to the Institution on its one-hundredth anniversary was the issuance by the Post Office Department of a special commemorative 3-cent postage stamp depicting the Smithsonian Building and containing the words "For the increase and diffusion of knowledge among men." The design was suggested by the Chancellor of the Institution, the late Chief Justice Harlan F. Stone. On the morning of August 10, 1946, in an impressive ceremony held in the auditorium of the National Museum, the first sheet of the Smithsonian stamps was presented to the Institution by Assistant Postmaster General Joseph J. Lawler on behalf of Postmaster General Robert E. Hannegan. The ceremony was broadcast by the National Broadcasting Co. through Station WRC, and music was furnished by the Navy Band Orchestra. Mr. Lawler concluded his remarks with these words:

"Thus it will be shown that the philanthropy of one man (James Smithson), coupled with the interest of another (Chief Justice Harlan F. Stone), made possible this commemorative postage stamp and brought together today this distinguished gathering of men and women to pay honor to an Institution whose record of achievement in the 100 years of its existence is well known throughout the civilized world. My one regret is that the late Chief Justice Stone, who played so important a part in making today's celebration a reality, is not present to enjoy the fruits of his labors for such a just and meritorious cause. Dr. Wetmore, it gives me great pleasure to present to you the first sheet of this Smithsonian Institution commemorative postage stamp."

In accepting the stamps on behalf of the Institution, I reviewed briefly the growth and expansion of the Smithsonian during the first 100 years of its existence, and concluded as follows:

"Such, in brief outline, is the Institution that today receives the signal honor of a commemorative United States postage stamp. For 100 years it has fostered diligently James Smithson's clear-sighted vision of the value to mankind of an institution devoted to the increase and diffusion of knowledge among men. At this milestone on its journey into the unknown future, the Institution dedicates itself anew to the promotion of Smithson's ideals.

"Mr. Lawler, on behalf of the Board of Regents of the Smithsonian Institution and for myself, I thank you for the recognition of the Institution's work expressed through this fine commemorative stamp,

and for this first sheet, which will have a place of honor in our philatelic collections."

Centennial publications.—To provide a permanent record of the Institution's hundredth anniversary, as well as to call public attention to the event, there was issued on August 10, 1946, the anniversary date, a book entitled "The First Hundred Years of the Smithsonian Institution," by Webster P. True, chief of the Institution's editorial division. In it are reviewed briefly the origin and development of the Institution itself and of the several bureaus that have grown up around the parent organization, its extensive work in the fields of research, exploration, and publication, and its function in times of war. Special attention was given to typographic design and to the illustrations, with the result that many commendatory letters have come from recipients of the book.

I also authorized the preparation of a complete list, with classified index, of all publications of the National Museum from 1875, the year in which the Museum began publication of a separate series, to 1946, the list to appear as a feature of the Centennial observance. The project was turned over to the editorial division, and the difficult task of preparing the classified index was undertaken by Miss Gladys O. Visel, of that division. It is hoped to issue the list before the close of the calendar year 1946. Copies will be placed in libraries and universities throughout the world, and the availability of such an index will greatly increase the usefulness of the Museum's publications to scientists and students.

Smithsonian Institution Centennial issue of "Science."—The journal "Science," official organ of the American Association for the Advancement of Science, very generously devoted the entire issue of August 9, 1946, to the Smithsonian Centennial. The editor of Science, Dr. Willard L. Valentine, named as guest editor for the issue Paul H. Oehser, assistant chief of the Smithsonian's editorial division. After an introductory statement by the Secretary outlining the developments and activities of the Institution, special articles by Smithsonian staff members review the various phases of its work, including astrophysics, anthropology, geology, biology, and engineering, as well as its publications, the International Exchange Service, its library, and the Smithsonian Deposit in the Library of Congress.

Centennial convocation.—On October 23, 1946, a Smithsonian convocation was held to mark in a more formal manner the Institution's one-hundredth anniversary. The event was timed to coincide with the fall meetings of the National Academy of Sciences and of the American Philosophical Society, the members of which, together with some 40 distinguished foreign scientists who attended their meetings, were the guests of the Institution for an evening affair in the Natural

History Building of the National Museum. There were felicitations by Dr. L. P. Eisenhart for the American Philosophical Society, and by Dr. F. B. Jewett for the National Academy of Sciences, with a response on behalf of the Institution by the Secretary, and an illustrated lecture by Dr. M. W. Stirling, Chief of the Bureau of American Ethnology, on the La Venta culture of southern Mexico, reviewing the scientific results of his 8 years of archeological work in that region in cooperation with the National Geographic Society. The addresses were followed by a reception to the National Academy and American Philosophical Society members and some 1,000 other scientists, educators, and Government officials.

Public notice of the Centennial.—On August 10, 1946, the White House issued as a news release a statement by President Harry S. Truman, who is *ex officio* Presiding Officer of the Institution. The statement is here quoted in full:

"On August 10, 1846, James K. Polk, eleventh President of the United States, put his signature on the act of Congress establishing the Smithsonian Institution. Today, August 10, 1946, we celebrate the one-hundredth anniversary of this venerable organization that is an American tradition.

"As presiding officer of the Institution, it is fitting that I, as President of the United States, should publicly take cognizance of this occasion.

"When James Smithson, an English chemist and mineralogist, died in 1829, it was found that he had left his fortune to the United States to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men. When Congress was notified of the unusual bequest, there arose a storm of debate, at times highly acrimonious, as to what to do with the gift. But finally, after some 8 years of discussion, sane counsel prevailed, the bequest was accepted, and the Smithsonian Institution was formally established under a broad definition of its proper functions.

"The act of foundation provides that the Smithsonian establishment shall consist of the President, the Vice President, and the Chief Justice of the United States, together with the heads of the Executive Departments. The managing body of the Institution is the Board of Regents, composed of the Vice President of the United States and the Chief Justice of the United States, *ex officio*, three Senators, three Representatives, and six eminent citizens. The executive officer directly in charge of the Institution's activities is the Secretary, chosen by the Board. There have been six eminent Secretaries: Joseph Henry, physicist; Spencer Fullerton Baird, biologist; Samuel Pierpont Lang-

ley, astronomer and pioneer in aeronautics; Charles Doolittle Walcott, geologist and paleontologist; Charles Greeley Abbot, astrophysicist; and the present Secretary, Alexander Wetmore, biologist.

"It is hardly necessary to state that this is the age of science—news-paper headlines remind us of this every day. Atomic power, jet propulsion, television, transmutation of elements, metals from sea water, penicillin—all these and many more present-day marvels trace back invariably to basic scientific investigation. In view of the more spectacular nature of recent discoveries in physics, chemistry, and medicine, and their adaptability to prompt economic application, we are likely to lose sight of the equal importance to mankind of research in such other sciences as anthropology, biology, and geology—sciences with which the Smithsonian Institution has been particularly concerned. Here, too, the steady progress made during the past 100 years has likewise contributed greatly to man's welfare, through a better knowledge and hence a fuller control of his environment, an understanding without which our present high hopes and plans for a united and peaceful world would have an even more difficult road to travel.

"For a full century the Smithsonian Institution has been a world center for the promotion of science, art, and other cultural activities. Congratulations are in order upon the Smithsonian's record in the advancement of science and culture during a most important century in the history of mankind, but this should be not merely a time for counting laurels. Rather it should be a time for further consideration of the ideals of the founder, James Smithson, and a renewal of the Institution's zeal in the increase of the sum total of man's knowledge. The Smithsonian should continue to strive toward the end that man should not only know better his earthly abode, but should acquire the means of knowing himself better. Such studies are of vital significance in our present efforts to build a better world order, and to break the cycle of recurring wars of ever-increasing destructiveness.

"On this one-hundredth anniversary of the founding of the Smithsonian Institution, may we accord all honor to the founder, James Smithson, for his lofty and far-seeing ideals. May the next 100 years bring even more glory to the name of the Institution and to that of its founder."

In addition to carrying the White House release, many leading newspapers and magazines printed special feature articles on the Smithsonian Centennial, and a number of radio commentators called attention to the event on their August 10 news programs.

Special Centennial exhibit.—With the aim of bringing the Institution's Centennial to the attention of the thousands of visitors who

through the Museum buildings every day, a special exhibit was opened on August 10 in the foyer of the Natural History Building. In separate alcoves were presented graphically by means of maps, photographs, specimens, and publications the various phases of Smithsonian work during the past 100 years. The alcoves covered origin and history, research, exploration, publications, art, and custodianship of the national collections.

POSITION OF THE INSTITUTION AFTER 100 YEARS

Before surveying the Institution's present position, I will introduce the subject by quoting a part of my general statement printed in the August 9 issue of *Science*, which was devoted to the Smithsonian Centennial.

"On August 10, 1846, the Smithsonian Institution came into being when James K. Polk, President of the United States, affixed his signature to the act of its foundation. For 100 years the Smithsonian has carried forward Smithson's ideal through scientific research in many fields, through world-wide exploration, through publications embodying the results of original investigation, and through other accepted methods of increasing and diffusing information.

"At the middle of the last century, Washington, the capital of our Nation, was a small city of some 50,000 inhabitants. Great expanses of unoccupied land lay beyond the Appalachian Mountains, and the detailed exploration of the vast area beyond the Missouri River was under way. The American Philosophical Society met in Philadelphia, certain other societies with scientific interests had been organized, and small natural history museums existed in a few centers, such as Harvard College and Charleston. Science in any of its branches was at best an avocation in this New World, except to a few individuals, and those Americans who had opportunity or leisure for scientific studies looked almost wholly for guidance to the Old World, whence they or their immediate ancestors had come. Into such a setting came the new Smithsonian Institution, to support and encourage scientific and cultural knowledge and to give to American science a powerful and far-reaching stimulus.

"Joseph Henry, first Secretary of the Smithsonian, set up a wise and far-seeing plan of organization, effective in the sound basic principles on which it rested, embodying close cooperation with other agencies and individuals, and looking to the cumulative advancement of knowledge. After Henry came Spencer Fullerton Baird, biologist, as second Secretary; then Samuel Pierpont Langley, astronomer and pioneer in aeronautical research; Charles Doolittle Walcott, geologist and paleontologist; and Charles Greeley Abbot, astrophysicist—all

distinguished men of science. From its early activities, bureaus grew up around the parent Institution—first the United States National Museum, then the International Exchange Service, the Bureau of American Ethnology, the National Zoological Park, and the Astrophysical Observatory. As the public value of these services became evident, their support was assumed in whole or in part by the Government, although they remained as bureaus of the Smithsonian Institution.

“In addition to its scientific activities, the Smithsonian is charged in its act of foundation with responsibility for national art treasures. The art feature has culminated recently in the National Gallery of Art, given to the Nation by Andrew W. Mellon and augmented richly by other philanthropists. The Gallery is established as a bureau of the Smithsonian Institution, but is directed by a separate board of trustees. The earlier art interests of the Institution are included in the National Collection of Fine Arts and the Freer Gallery of Art. The latter, presented and endowed by Charles L. Freer, is devoted chiefly to the Oriental field, and through its highly valuable archeological materials will figure more and more importantly in strictly scientific studies.

“From one building, a small staff, and a single publication, the Institution has grown in a century until it now occupies five buildings on the Mall and numerous structures at the National Zoological Park, while it issues 14 series of publications, each devoted to a particular sphere.”

As the Institution goes into the second century of its existence, its position is strong in some respects and weak in others. Its work in the increase and diffusion of knowledge over the past 100 years has established for it a national and international reputation among scholarly organizations, providing unquestioned entree into any field of cultural endeavor anywhere in the world. On the staffs of its scientific bureaus—namely, the United States National Museum, the Bureau of American Ethnology, and the Astrophysical Observatory—are highly trained specialists in several branches of science, many of them ranking among the leaders in their respective fields. In the National Museum, vast study collections in biology, geology, and anthropology offer unlimited opportunity for fertile investigations in those fields. The three bureaus of the Institution devoted to art—the National Gallery of Art, the National Collection of Fine Arts, and the Freer Gallery of Art—all comprise splendid art collections in their respective fields, together forming a growing aggregation that makes Washington one of the world's art centers.

On the other side of the picture, weaknesses exist in several directions. The collections and essential staff of the Institution and its

various bureaus have long since outgrown the present housing facilities and physical equipment. Many of the Institution's activities, both scientific and administrative, are undermanned, leading to some degree of failure to enter upon desirable new enterprises. Financial resources, public and private, should be increased to promote the Institution's opportunities for advancement of knowledge through research and publication. The public exhibits in the National Museum, viewed by more than 2,000,000 visitors each year, require modernization, begun in 1940 but postponed because of the war. Resources available for printing and binding have not been sufficient to enable the Institution to keep pace with the manuscript output of the scientific staff or to keep abreast of the necessary binding in the Smithsonian library of 1,000,000 volumes. This condition has led to the creation of a large backlog of unpublished scientific manuscripts, and of unbound periodicals in the library.

The first step toward improvement is the recognition of weaknesses. Having outlined important ones, I may take some satisfaction in stating that plans are now shaping up to remedy them. A building program to relieve the present overcrowding is already outlined, and the outlook is bright that before many years more building space will be available to assure proper operation and normal expansion. Definite efforts have already been started to obtain funds to increase the personnel where it is most needed, to make a beginning on modernization of exhibits, and to keep more nearly abreast of the manuscripts produced by the scientific staff, so essential to the Institution's responsibilities in the diffusion of knowledge.

When the Smithsonian Institution was founded 100 years ago, it stood almost alone in America as an organization devoted solely to the promotion of science and of learning in general. During the first century of its existence, other large foundations have come into being—some of them with far larger resources—until today there are in America scores of research institutions and laboratories, some of them independent foundations, some attached to universities, and others forming essential parts of large industrial concerns. While many of these are restricted to specific lines of scientific work, the Smithsonian Institution has no limitation in scope of activity as long as its endeavors operate to increase and diffuse knowledge. It can therefore enter into any new fields of investigation that are feasible with the funds and personnel at its command, but in order to make its work most effective in the increase of knowledge, the Institution must now plan carefully to avoid duplicating the efforts of other research organizations.

At the close of its first century of operation and standing at the threshold of the second century, the Institution's first concern will be

to continue to execute faithfully the trust reposed in the United States of America by James Smithson, its founder, more than 100 years ago.

PROPOSED NEW BUILDINGS

On October 3, 1945, H. R. 4276, the Public Buildings Act of 1945, was introduced in Congress and referred to the Committee on Public Buildings and Grounds. The part that concerns the Institution reads as follows:

"Sec. 202. The Federal Works Administrator is hereby authorized, under the provisions of the Public Buildings Act of May 25, 1926, as amended (40 U. S. C. 341-347), to acquire land where necessary and to construct for the Smithsonian Institution the following buildings and facilities:

(a) A building on a suitable site in the Mall for a historical museum to include space for the exhibition of the historical collection of the Nation, including naval and military collections, memorabilia of noted Americans, philately, and numismatics, under a total limit of cost of \$6,600,000.

(b) A building for the engineering and industrial collections of the Nation, including aviation, under a total limit of cost of \$9,150,000.

(c) Additional facilities at the National Zoological Park, including an aquarium, a lion house, an antelope house, a monkey house and monkey island, and barless pits and paddocks, under a total limit of cost of \$2,645,000."

If this bill becomes a law and the funds authorized are appropriated, the very extensive and valuable national collections in the fields of history and engineering and industries could be properly housed and exhibited to the public. The exhibits in these fields, which are among the most interesting of all to visitors, are at present crowded together in one building erected 67 years ago and now entirely inadequate for the purpose.

To anticipate slightly the next fiscal year, the President approved on August 12, 1946, an act to establish a national air museum as a bureau of the Institution and to authorize the appropriation of certain funds for the purpose. When funds are made available to carry out the purposes of this act, the present intolerably overcrowded condition of the national aeronautical collections will be alleviated. The vitally interesting historical aircraft, engines, and other aeronautical material now in the collections are housed in a steel structure built during World War I and later turned over to the Institution to accommodate temporarily the growing aircraft collection. This building is now full to overflowing, leaving no space to exhibit material illustrating the tremendous recent advances in aeronautics.

It is the earnest hope of the Institution that these proposed buildings will become actualities in the near future to the end that the priceless national collections may be properly safeguarded and exhibited to the ever-increasing number of visitors from all parts of the country.

CANAL ZONE BIOLOGICAL AREA

Under the President's Reorganization Plan No. 3, the biological station on Barro Colorado Island, known as the Canal Zone Biological Area, was placed under the administration of the Smithsonian Institution on July 16, 1946. This area in Gatún Lake was set aside by a 1940 act of Congress in order to preserve in its original state the fauna, flora, and other natural features for study by scientists, particularly those from North, Central, and South America.

The Barro Colorado station has been maintained as a Federal agency since 1940 by contractual arrangements with other Federal agencies and by fees subscribed by American scientific institutions. The income from this method of support has not, however, been sufficient to maintain the laboratories and other facilities in good condition, and the Institution's first concern upon taking over this new responsibility will be to obtain funds for rehabilitation of the physical plant and the proper equipping of the laboratories and other buildings.

The reorganization plan was not actually approved until shortly after the close of the fiscal year, so that further discussion of the project will be reserved for the next report.

FOURTEENTH ARTHUR LECTURE

Under the terms of the will of the late James Arthur, of New York, the Smithsonian Institution received in 1931 a fund, part of the income from which should be used for an annual lecture on some aspect of the science of the sun.

The fourteenth Arthur lecture, entitled "The Sun and the Harvest of the Sea," was given by Dr. Waldo L. Schmitt, head curator of biology of the National Museum, on March 5, 1946. This lecture, with illustrations, will be published in the Annual Report of the Smithsonian Institution for 1946.

SUMMARY OF THE YEAR'S ACTIVITIES OF THE BRANCHES OF THE INSTITUTION

National Museum.—In this first year after the end of the war there were marked increases in the number of specimens accessioned and in the number of visitors, and field expeditions began again to go out from the Museum after having been held in abeyance during the war years. Outstanding among the year's accessions were the following: In anthropology, 6,765 artifacts from protohistoric Indian sites in Kansas

and adjoining States, 226 specimens from Ezion-geber in Trans-Jordan, and documented field collections from Melanesian villages of northeastern New Guinea; in biology, large numbers of specimens from the Pacific area, most of them resulting from activities of military and naval organizations or personnel, including birds and mammals from the South Pacific and the Orient, fishes from the Marianas, 10,000 mosquitoes from various Pacific islands and Burma, and plants from the Admiralty, Aleutian, Caroline, and Solomon Islands, and other Pacific areas; in geology, specimens of four minerals not hitherto represented, sal-ammoniac crystals and other sublimates from the new Mexican volcano, Parícutin, and large collections of fossil invertebrates from various localities in the United States; in engineering and industries, 3 electromechanical tabulating machines and several high-speed precision gages, 2 early commercial sewing machines of 1858 and 1874, and a specially designed exhibit illustrating the contributions of the mineral kingdom to materia medica; in history, a Japanese parachute found in New Guinea, 37 models of United States, French, and British warships of World War II, and 4 dresses dating from 1814, 1855, 1861, and 1894 for the collection of American period costumes. Field work included insect studies in Colombia, a survey of the fish and game resources of Guatemala, a survey of the fauna of Bikini Atoll in connection with the atom-bomb tests, studies of the bird life of Panamá and of Colombia, and fossil collecting in various parts of the United States. Visitors for the year totaled 2,115,593, an increase of nearly 400,000 over the previous year. The Museum published two Annual Reports, six Bulletins, and five Proceedings papers.

National Gallery of Art.—Six new gallery rooms were completed and opened to the public on February 2, 1946, and a contract was entered into for the installation of additional air-conditioning equipment. The Gallery continued to receive many valuable gifts of paintings, sculpture, decorative prints and drawings, and one painting "Siegfried and the Rhine Maidens," by Albert P. Ryder, was purchased with Gallery funds. Traveling exhibitions of water colors and drawings from the collection of the Index of American Design and prints from the Rosenwald Collection were shown at a number of art galleries and museums. The Gallery accepted for safekeeping 202 paintings from German museums; these have been placed in storage until conditions in Germany insuring their proper care have been reestablished. The staff prepared a number of books and catalogs on the Gallery collections, and contributed articles to outside art journals. The second edition of "Masterpieces of Painting from the National Gallery of Art" was placed on sale, and a third edition was being prepared. A new edition of the General Information booklet, for

free distribution to visitors, was issued, and the sale of postcards, color reproductions, and moderately priced catalogs was continued. The Sunday evening concerts in the East Garden Court, and the daily 10-minute talks on "The Picture of the Week," were continued with undiminished popularity. The total number of visitors to the Gallery was 1,947,668.

National Collection of Fine Arts.—The twenty-third meeting of the Smithsonian Art Commission was held on December 4, 1945, when four art works submitted during the year were accepted for the National Collection. Resolutions were adopted on the death of Herbert Adams, a member of the Commission, and John Taylor Arms was recommended to succeed him. To succeed Edward W. Redfield, who resigned during the year, the Commission recommended Eugene E. Speicher. Two miniatures were acquired through the Catherine Walden Myer fund, and two pieces of pottery through the Reverend Alfred Duane Pell fund. Eleven special exhibitions were held during the year, as follows: The Honorable William D. Pawley collection of 27 portraits of "Flying Tigers" by Raymond P. R. Neilson, N. A.; 28 sculptures by Genaro Amador Lira, of Nicaragua; 20 portraits of members of the Lafayette Escadrille, by John Elliott; the Eighth Metropolitan State Art Contest, comprising 412 paintings, sculpture, prints, and metalcraft; the forty-fourth annual exhibition of miniatures by the Pennsylvania Society of Miniature Painters, consisting of 100 miniatures; 53 portraits by Alfred Jonniaux; A Century of the Greeting Card, courtesy of Brownie's Blockprints, Inc.; 53 oil and water-color paintings by Charles P. Gruppe; 54 paintings of Siam by students of the School of Arts and Crafts, Bangkok; Biennial Exhibition of the League of American Pen Women, including 582 art objects; and the Scholastic Calendar Art Competition, including 150 paintings.

Freer Gallery of Art.—Additions to the collections included Chinese bronze, painting, and pottery, Bactrian and Chinese metalwork, a Korean gold ornament, and a Chinese manuscript. The work of the staff was devoted to the study of new accessions and of objects submitted for purchase; general research work within the collections of Chinese, Japanese, Arabic, Persian, and Indian materials; the preparation of material for publication and the revision of earlier work; docent service, and public lectures. Reports were made upon 1,612 objects and 408 reproductions of objects submitted for examination, and 132 Oriental language inscriptions were translated. The total number of visitors to the Gallery for the year was 97,822, and 1,625 persons visited the main office for various purposes. Members of the staff made several trips out of Washington on official business connected with the work of the Gallery. Miss Grace Dunham Guest,

Assistant Director, retired June 30, after 26 years of service with the Gallery, and was given the honorary title of Freer Gallery of Art research associate. John A. Pope, associate in research, and William R. B. Acker, associate in languages, returned to the Gallery from absence on war duty.

Bureau of American Ethnology.—The Smithsonian Institution-National Geographic Society archeological project in southern México was carried forward by Dr. M. W. Stirling, Chief of the Bureau, assisted by Dr. Philip Drucker of the Bureau staff. Twenty-four stone monuments were located, including altars, statues, and monolithic heads of Olmec and La Venta type. Dr. Frank H. H. Roberts, Jr., Assistant Chief of the Bureau, was designated director of the archeological surveys and excavations of Indian sites to be flooded by proposed dam construction in various river basins, to be conducted under Smithsonian administration in cooperation with the National Park Service, the Corps of Engineers, and the Bureau of Reclamation. A large part of his time during the year was devoted to this extensive project. Dr. John P. Harrington continued his study of Indian languages, producing a Kiowa grammar of 405 manuscript pages. Later in the year he pursued linguistic studies in New Mexico and California. Dr. Henry B. Collins, Jr., directed the closing operations of the ethnogeographic board for 6 months after its dissolution on December 31, 1945, and then resumed his research on Eskimo archeology. He attended several meetings of the board of governors of the Arctic Institute of North America in Montreal. Dr. William N. Fenton continued his study of the place names of the Cornplanter Senecas and collected material relative to the Condolence Council for installing chiefs in the Iroquois League. In connection with his Iroquois studies, Dr. Fenton attended the First Conference on Iroquois Research at Allegany State Park, N. Y., October 26–28. Dr. Gordon Willey completed a 50,000-word manuscript on “Excavations in Southeast Florida” and a 25,000-word article on South American ceramics for inclusion in the Handbook of South American Indians. He also assisted Dr. Roberts in preparing preliminary plans for the Federal Valley Authority archeological program. At the end of the fiscal year he was engaged in archeological work in the Virú Valley in northern Perú. The Institute of Social Anthropology, an autonomous unit of the Bureau under the directorship of Dr. Julian H. Steward, continued its program of cultural and scientific cooperation with the other American republics by a transfer of funds from the Department of State. University courses and field researches were conducted in México, Perú, and Brasil in cooperation with cultural organizations of those countries, and several publications resulting from the field

work were in press. Miss Frances Densmore, a collaborator of the Bureau, submitted three papers on Indian music and a complete bibliography covering 50 years of study of American Indian music. The Bureau issued one Annual Report, one Bulletin, two volumes of the Handbook of South American Indians, and one publication of the Institute of Social Anthropology.

International Exchanges.—The International Exchange Service is the official agency of the United States for the exchange of governmental and scientific publications between this country and all other countries. During the war shipments to many countries were necessarily suspended; but during the past year most of these shipments have been resumed, and accumulated material being held at the Institution was reduced from 3,512 boxes to 1,109. The number of packages passing through the exchanges totaled 540,502, which included 3,117 boxes shipped from the Institution, an increase of 2,134 over the previous year; the total weight of the material handled was 472,299 pounds. The average weight of the individual packages was nearly double that of the year before, indicating that institutions are sending out some of the material held up by the war.

National Zoological Park.—During the war years, because of shortage of personnel, maintenance of buildings and grounds was necessarily neglected to some extent. Although the return to prewar maintenance standards has been hampered by the difficulty of recruiting trained personnel, nevertheless the past year witnessed a perceptible improvement in general conditions throughout the establishment. The Park urgently needs new buildings to replace the remaining antiquated structures still being used to house animals, and preliminary planning has been discussed with the Public Works Administration for construction of these buildings when conditions justify such work. The number of visitors for the year showed a marked increase over the previous year, owing to the removal of the wartime ban on pleasure driving and to the general increase in civilian travel. The total number of visitors was 2,372,337, an increase over the fiscal year 1945 of 265,253. Although the number of rare or unusual animals has naturally decreased somewhat under wartime conditions, the reduction is largely offset by an increase in number of the commoner kinds. Rarities gradually began to come in again during the year, and it is anticipated that normal growth in this respect will now be resumed. At the close of the year the population of the Zoo numbered 2,553 individual creatures, representing 701 different species.

Astrophysical Observatory.—Final tabulation was made of the solar-constant values for the calendar year 1945. A new vacuum bolometer, designed at the Observatory, will eliminate gradual loss

of sensitivity. Under the terms of a contract with the Office of the Quartermaster General, the Observatory is making a detailed study of sun and sky radiation at Camp Lee, Va., as part of the program to determine causes of tent-fabric deterioration. Eight copies of a special instrument based on the sensitive, quick-acting thermoelement developed at the Observatory have been installed and put into operation at Camp Lee. A large volume of information is accumulating concerning the amount and kind of radiation, for each hour of each day, that falls on the tents being tested. Observations continued at the three field stations until February 1946, when the Tyrone, N. Mex., station was closed. The equipment will be installed temporarily at a sea-level location in Florida to study transmission of radiation through water vapor. Dr. Abbot published two papers dealing with his studies of the correlation between solar activity and weather changes. In the Division of Radiation and Organisms, experiments have been carried on in connection with improving the accuracy of apparatus used in determining the amount of carbon dioxide absorbed by green plants in the process of photosynthesis. The study of plant growth under controlled artificial conditions of mineral nutrition, illumination, temperature, and humidity has been continued. Further improvement of technique is being studied.

PUBLICATIONS

The Institution's several series of publications constitute its chief means of carrying on the "diffusion of knowledge," which joins with the "increase of knowledge" to form the purpose of the Institution as stipulated by the founder, James Smithson. The Smithsonian publication program started in 1848 with one series, the Smithsonian Contributions to Knowledge, and as the Institution's research work expanded over the years, other series were established to contain the several phases of its investigations until today the Smithsonian imprint appears on 14 distinct series. At the end of its first full century of existence, the Institution has issued some 7,500 individual publications, of which 12,000,000 copies have been distributed. As the great majority of these works are the result of original researches, a large volume of basic new knowledge has been made available to the world through Smithsonian publications. It has been stated on numerous occasions that few textbooks or encyclopedias exist that have not drawn to some extent on publications of the Smithsonian Institution.

Among the outstanding papers issued during the year may be mentioned "A Bibliography and Short Biographical Sketch of William Healey Dall," by Paul Bartsch, Harald Rehder, and Beulah E. Shields; "Sunspot Changes and Weather Changes," by H. H. Clayton; "An

Annotated Checklist and Key to the Snakes of Mexico," by Hobart M. Smith and Edward M. Taylor; "The Birds of Northern Thailand," by H. G. Deignan; "The Indians of the Southeastern United States," by John R. Swanton; and volumes 1 and 2 of the Handbook of South American Indians, edited by Julian H. Steward.

A total of 64 publications was issued during the year, and 129,750 copies of publications in all series were distributed.

LIBRARY

With the ending of the war early in the fiscal year, and the gradual improvement in shipping conditions, the transmission of material from European countries was resumed, and receipts increased in frequency and number, the total number of accessions recorded being 37,143. Also, the library was able to send abroad several thousand pieces from its stock of duplicates to assist in the rehabilitation of destroyed libraries. Among the 1,303 books purchased were a number of out-of-print works which are noteworthy not so much for their rarity as because they fill some special gaps in the collections. Outstanding among the gifts of books and pamphlets was the late Charles W. Gilmore's private collection of 600 volumes and hundreds of reprints and separates on vertebrate paleontology which was presented to the library by Mrs. Gilmore. The total recorded volumes in the library at the end of the fiscal year was 928,353; of this number 5,279 were accessioned this year. Two hundred and sixty-two new exchanges were arranged; 6,259 specially requested publications were received; 6,124 volumes and pamphlets were cataloged, 25,326 cards were added to catalogs and self lists, and 12,947 periodical parts were entered; loans totaled 10,225. There were 820 volumes sent to the bindery, and 1,010 volumes were repaired in the Museum. The most urgent of the library's needs continues to be more and better-arranged shelf room. There is also need of an increase in the library staff for cataloging and for systematic work on the large collection of duplicates.

Respectfully submitted.

A. WETMORE, *Secretary.*

APPENDIX 1

REPORT ON THE UNITED STATES NATIONAL MUSEUM

SIR: I have the honor to submit the following report on the condition and operation of the United States National Museum for the fiscal year ended June 30, 1946.

Appropriations for the operation of the National Museum for the year totaled \$991,053, including funds for the increase, study, exhibition, and preservation of the national collections; for maintenance, repair, operating, and guarding all the buildings of the Smithsonian group; and for printing and binding. This amount represented an increase of \$52,059 over the previous year.

COLLECTIONS

Approximately 379,000 specimens came to the Museum's collections during the year, received in 1,594 separate lots. The five departments registered specimens as follows: Anthropology, 9,026; biology, 320,037; geology, 45,163; engineering and industries, 1,480; history, 3,600. Most of the accessions were acquired as gifts from individuals or as transfers by Government departments and agencies. The complete report on the Museum, published as a separate document, includes a detailed list of the year's acquisitions, of which the more important are summarized below. Catalog entries in all departments now total 18,820,000.

Anthropology.—Prehistoric specimens received derived from such diverse parts of the world as Trans-Jordan, Italy, Ecuador, México, and the United States. They include 6,765 artifacts from protohistoric Indian sites in Kansas and adjoining States; 226 specimens from Ezion-geber, seaport to King Solomon's copper smelters, on the north shore of the Gulf of Aqabah, Trans-Jordan; a carefully documented series of 193 potsherds from surface sites throughout Trans-Jordan; 486 diverse artifacts from the highlands of México; 149 stone, earthenware, and copper artifacts from the former Cherokee region of Tennessee and North Carolina; 17 earthenware vessels of Daunian ware from Apulia, Italy; and a hammered ox with cut-out figures from Loja Province, Ecuador.

In ethnology, major documented field collections came from Melanesian villages of northeastern New Guinea, including objects of

many different kinds, some of which were hitherto unrepresented in the Museum's collections. A unique specimen in the form of a carved altar stone was presented by Admiral William F. Halsey, who had received it from a New Caledonian native chief. Other important ethnologic material came from the Southern Shan States, Korea, Java, and Sumatra. The North American Continent was represented by two outstanding accessions: one a collection of basketry, skin garments, and dance robes obtained in 1890 from the Hupa Indians of central California and from the Indians of the Great Plains, and the other a collection of weavings from the Navaho and Chilkat Indians. A specimen of antiquarian interest was a copy of the Holy Bible, with the Apocrypha, which was printed from stereotype plates originally used for the third (1819) edition of the Isaac Collins Bible. In addition, several dozen pieces of antique glassware were added to the ceramics collections. The section of period art and textiles received an important collection of 10 pieces of Belgian needlepoint and bobbin-made laces dating from the period of World War I.

To the physical anthropology division came about 430 specimens of Indian skeletal remains from various counties in Illinois, Arkansas, and Missouri, and also skeletal material from Calhoun, Jersey, and St. Claire Counties, Ill. Twenty-one cleared human fetuses were added to the valuable embryological collection received last year.

Biology.—Nearly twice as many biological specimens were received this year as the previous year.

Large numbers of birds and mammals from the South Pacific region and the Orient came by transfer from the Army Medical School, the Naval Medical School, and the U. S. A. Typhus Commission, while several hundred North American mammals and birds were transmitted by the United States Fish and Wildlife Service. Five handsome bear-skins and skulls and an unusually well-prepared skeleton of a beaked whale from La Jolla, Calif., were among other outstanding mammalian gifts. Ornithological field work in Colombia under the W. L. Abbott fund yielded about 1,350 birds to the Museum's collections. Nearly 650 birds were collected for the Museum in Darién, Panamá, and 60 from the atom-bomb test site at Bikini Atoll. Other important avian specimens from Admiralty Islands, Manchuria, Ceylon, Perú, Venezuela, and Canada found their way to the Museum's division of birds. Reptiles and amphibians were added to the number of 2,177, about two-thirds of which were received from the Naval Medical Research Unit No. 2 or from Service personnel. In addition, about 125 herpetological specimens resulted from the Smithsonian Institution-National Geographic Archeological Expedition in México; 85 came from a donor in Haiti; and 20 taxonomically important frogs from Brasil.

About 20,000 specimens of fishes were received during the year, among which were the following large lots: About 3,800 from the Marianas, collected by the Naval Medical Research Unit No. 2; about the same number transferred from the United States Fish and Wildlife Service, 1,000 from Chile, and 2,800 from Louisiana and Texas; and 2,200 fresh-water fishes from southern California. Smaller lots containing much fine material, including many paratypes, came from Australia, Venezuela, Colombia, Guatemala, the Philippines, the South Pacific, California, and Baja California, through the generosity of various donors.

Several large lots of insects were received, the most important one both scientifically and economically being a collection of more than 10,000 mosquitoes and 4,000 slides of chigger-mites from various Pacific islands and Burma, transferred from the Naval Medical Research Unit No. 2 and the U. S. A. Typhus Commission. Another 10,000 miscellaneous insects collected on Guam were contributed by various members of the armed forces. While cooperating with the Mexican Government in an economic geological survey in México, Dr. W. F. Foshag, the Museum's curator of mineralogy and petrology, obtained 2,500 miscellaneous insects for the National Museum. The largest entomological accession of the year was a transfer of about 140,000 specimens from the United States Department of Agriculture, a large part of which represents insects sent in by Army and Navy sources for identification.

To the division of marine invertebrates came more than 5,000 new specimens. Of these about 1,250, mostly crustaceans, were sent by members or former members of the armed services stationed in the Pacific region, the Aleutian, Hawaiian, and Marshall Islands, Okinawa, and Japan. Other accessions of interest included a lot of 950 invertebrates collected in Guam, Rota, Okinawa, Pelelieu, and the Palau Islands and forwarded by the Naval Medical Research Unit No. 2; 25 barnacles from the Bureau of Ships; and small lots of crustaceans and leeches from the Army Medical Museum, the Army Medical School, and the Eighteenth Medical General Laboratory. Included in the material received in the division of mollusks were a considerable number of type specimens. Transfers from the Army Medical Museum, the Army Medical School, and the Navy Medical School yielded 850 mollusks, chiefly fresh-water gastropods, from the Philippines, Okinawa, and Guam. Over 4,000 Japanese and Philippine mollusks came from one donor, nearly 900 Philippine shells from another, 850 land and fresh-water shells from Virginia from another, and 1,840 Colombian mollusks from still another. In all, about 20,000

mollusks were added to the collections. The helminthological collections were materially enhanced by the generous bequest of the lifetime collections of the late Dr. Henry Baldwin Ward, distinguished parasitologist; 8,000 lots of helminths, including many types, were received from Professor Ward's daughter.

The number of plants received jumped from about 30,000 in 1945 to nearly 42,000 in 1946, largely as a result of extensive collections made by members of the armed forces while serving in the Admiralty, Aleutian, Caroline, Galápagos, Solomon and Philippine Islands, Guam and other Marianas, Japan, Okinawa, New Guinea, Burma, and France. The herbarium received 3,100 Burman plants by transfer from the U. S. A. Typhus Commission, and over 300 Ecuadorian plants from the Foreign Economic Administration. Other important lots, from private donors, came from Colombia, Venezuela, and México. Noteworthy botanical collections totaling 6,800 specimens were made for the Museum in Panamá and the Dominican Republic. In addition, about 5,000 plants were added to the herbarium as a result of exchanges arranged with other institutions, in Europe, South America, Cuba, Canada, and the United States.

Geology.—The department of geology accessioned 45,000 specimens during the year, nearly double the number for last year, about 90 percent of these being assigned to the division of invertebrate paleontology and paleobotany.

The mineral collection continued its growth, partly through the several Smithsonian funds available for the purchase of specimens, but largely through gifts. Three new minerals not hitherto represented—cattierite, valsite, and salesite—were donated, while the new species sampleite was obtained by exchange. The mineral collection of Dr. Whitman Cross, containing specimens from many old classical localities in Europe and the western United States, came as a gift and added much historically interesting material. Geological field work in México by Curator W. F. Foshag yielded fine sal-ammoniac crystals and other sublimates from the newborn volcano Parícutin, and examples of rare mercury minerals from Huahauxtla, Guerrero. The principal addition to the rock series also came from Dr. Foshag's visits to Parícutin and comprised an extensive collection of lavas, ash, and other eruptive products. Extensive sets of mercury ores, copper, and fluorspar were also included in Dr. Foshag's Mexican material.

Three meteorites not previously represented in the Museum's series were added: A slice of the Pine River, Wis., meteorite; a 3,576-gram specimen of the Dimmitt, Castro County, Tex., fall; and a piece of the Livingston, Tenn., occurrence.

The most important additions to the gem collection came as transfers from the Procurement Division of the Treasury Department. They include a large blue topaz, three fine aquamarines, an amethyst, and a tourmaline. Other outstanding gems were procured through the Canfield, Roebling, and Chamberlain funds.

The following were noteworthy additions to the collections of fossil invertebrates: 367 type specimens of Middle Cambrian brachiopods and trilobites from Montana; 425 Middle Ordovician specimens from the unique cryptovolcanic structure at Kentland, Ind.; 750 bryozoans, corals, and other classes from the Middle Ordovician of Virginia and Tennessee; and 700 Devonian brachiopods from southwestern Ontario. From the Upper Paleozoic rocks donations included 180 Pennsylvanian and Permian gastropods from New Mexico, 500 Pennsylvanian fusulines, about 5,000 Pennsylvanian fossils from near St. Louis, Mo., and 250 from near Moab, Utah. Gifts through the Springer and Walcott funds added other worthy Paleozoic fossils, including 2,100 Cenozoic mollusks from the Lord Calvert collection. Field trips conducted under the Walcott fund by Curator G. A. Cooper and his associates resulted in about 5,000 specimens of Ordovician invertebrates from Alabama, Georgia, Tennessee, and Virginia, a similar number from the Mississippian and Pennsylvanian rocks of central Texas, and an equally large lot of Upper Paleozoic fossils from west and central Texas, together with 400 blocks from west Texas containing silicified fossils for etching. The division also received 3,500 slides of Cretaceous Foraminifera from Arkansas and 50 from Perú. Other gifts included important Cenozoic material, for example: 4,000 fossil fresh-water shells, 1,070 Tertiary fossils, and about 75 Pleistocene fresh-water gastropods from Utah. Important collections transferred from the United States Geological Survey comprised about 3,700 types of Carboniferous and Permian fossils described by the late Dr. George H. Girty; 200 Jurassic invertebrates from Wyoming; 585 Cretaceous ammonites from Wyoming; and 1,000 Devonian and Mississippian fossils from the Central Mineral Region of Texas. In addition, several hundred specimens were received by exchange with other institutions and individuals.

In the division of vertebrate paleontology there was a decrease of material coming in, owing largely to the fact that no expeditions to obtain fossil vertebrate specimens could be sent out until just before the year's end. The extreme rarity of fossil bird remains made noteworthy the gift of vertebrae, mandibles, and other bones of the double-crested cormorant *Phalacrocorax auritus* from Pleistocene deposits in Florida. Five fossil examples of the puzzling egg capsules of chimaeroid fishes from the Upper Cretaceous rocks of México and

elsewhere were transferred from the United States Geological Survey. Other fossil vertebrate additions included a mammoth tooth found in the mountains of Ecuador, 13 fossilized specimens of the fish *Mallotus villosus* from western Greenland, and a partial skull of the porpoise *Eurhinodelphis* from the Calvert formation in the Chesapeake Bay region.

Engineering and industries.—This department experienced a sub-normal year in the matter of new accessions, there being a drop from last year of about 50 percent in total number of specimens received. Among the year's total of 1,480, however, there are several worthy of special mention.

In engineering, a group of three Hollerith electromechanical tabulating machines and several high-speed precision gages were presented by two interested corporations. The United States Maritime Commission transferred six models of ships representing classes of standard cargo and passenger vessels procured by the Commission during the war. There also came a scale model of the Baldwin-Westinghouse, geared, steam-turbine locomotive, first introduced in 1945. In the section of aeronautics two groups of models were received—one a collection of 19 United States Navy types of the period following World War I, transferred by the Bureau of Aeronautics, and the other a collection of aircraft recognition models made by school children early in World War II, presented by the United States Office of Education.

The Office of the Quartermaster General, Army Service Forces, and the Bureau of Supplies and Accounts, Navy Department, transferred 141 specimens of the various fabrics used by the services in World War II, made according to standard Government specifications. Various manufacturers continued to supply examples of new fabrics to keep the textile exhibits up to date. Two early commercial sewing machines were received, dating from 1858 and 1874. A number of additions were made to the collections of early homecraft textiles, including coverlets, carpeting, and needlework.

Specimens added to the collections representing the chemical and agricultural industries included examples of the applications of the newer plastics, and an 1885 Babcock milk tester. The most valuable accession in the division of medicine and public health was a specially designed exhibit illustrating the contributions of the mineral kingdom to materia medica. In the section of woods and wood technology an outstanding gift was a series of 100 British Honduras woods, from the Honduran conservator of forests. Other desirable wood specimens came from the Philippine Islands and Perú.

Charles W. Dahlgreen, artist, presented 18 additional copper plates of his etchings and drypoints, making 94 in all, which are being used for printing the Smithsonian edition of his work (described in last year's report). Mr. Dahlgreen also gave 126 drypoints and etchings and 1 block print in color, further representative of his life work in the field of printmaking. Another interesting gift in graphic arts was Walter Tittle's "Arms Conference Memorial Folio" containing 25 autographed drypoint portraits of statesmen who attended the Conference on Limitation of Armaments, 1921-22. Historically valuable photographic equipment received included the machines used in Germany as early as 1904 by Dr. Arthur Korn in transmitting photographs by electricity; a radar camera of World War II; and a motion-picture camera and projector dating from about 1885, which came as a loan.

History.—About twice as many specimens were received in the division of history this year as last year. Accessions to the costumes collection were noteworthy. The dresses that since 1915 have represented the administration of President Benjamin Harrison in the collection of dresses of mistresses of the White House, were presented to the Museum. Mrs. Calvin Coolidge presented a fan, neck-lace, and handkerchief to go in the case containing the dress of Mrs. Coolidge presented by her in 1930. The general collection of American period costumes was enriched by the addition of four dresses dating, respectively, from 1814, 1855, 1861, and 1894—each in an excellent state of preservation and each a fine example of the period it represents.

The military collection was increased by the gift of a Japanese parachute found in New Guinea. A collection of United States Army insignia and a series of topographic maps, all of World War II, were received from the War Department. To the naval collection were added 37 models of United States, French, and British warships of World War II, and more than 700 pieces of naval insignia, from the Navy Department.

The numismatic collection was increased by about 100 coins and medals and the philatelic collection by 1,700 postage stamps.

EXPLORATIONS AND FIELD WORK

Although field explorations during the year were not extensive, they represented a return toward the regular schedule of such activities in times of peace.

Dr. E. A. Chapin, curator of insects, in connection with the State Department's program for the promotion of cultural relations with

scientists in other American countries, left on April 25 for Colombia. During May he was at the Instituto de Ciencias Naturales of the National University in Bogotá, where he was occupied in consultations with government entomologists in connection with cooperative investigations, particularly on certain groups of Coleoptera of economic importance. There was opportunity at the same time for field studies in a variety of climatic zones ranging from Villavicencio in the tropical lowlands at the eastern base of the Andes to the high mountain passes above Bogotá. In June, Dr. Chapin continued to Medellín, where he was occupied for several days with Prof. F. Luis Gallego in examining insect collections at the Facultad de Agronomía. This was followed by similar work in Cali and Palmyra with Belisario Losada, and at Popayán in the Universidad del Cauca. He returned to Washington on June 30.

Dr. Robert R. Miller, associate curator, division of fishes, was assigned to a survey of the fish and game resources of Guatemala, a cooperative project of the Fish and Wildlife Service of the Department of the Interior and the Guatemalan Government, with the participation of the Smithsonian Institution. Investigations began in March and continued until the end of May, Dr. Miller being occupied mainly with studies of the fresh-water fishes of the plateau area. Collections were made principally above 3,000 feet, covering many lakes and streams. In addition there was opportunity for briefer studies along the middle Motagua River and in Lake Ysabal. The work in the main was in the nature of reconnaissance with expectation of continuing in greater detail another season. The present collections, now under study, are yielding much data of interest.

In connection with the atom-bomb tests at Bikini, Dr. Leonard P. Schultz, curator of fishes, and Dr. J. P. E. Morrison, assistant curator, division of mollusks, left in February to begin a detailed survey of the fauna of the atoll. It was expected that a careful check would be made of conditions following the bomb explosions. The studies of Dr. Schultz are concerned with fishes in the lagoon and along the reefs to obtain data on the kinds present and on their relative abundance. Dr. Morrison is occupied with mollusks and other marine invertebrates on the reefs, and also with detailed collections of the land animals present, including the birds. There has been opportunity also for comparative studies at several other atolls in the Marshall Islands. The extensive series of specimens already obtained will serve as an index to the forms found, and will be especially important also as the first collections in the Museum from this area. This work was still under way at the close of the year and will be reported in more detail next year.

At the beginning of March, Dr. Alexander Wetmore, Secretary of the Smithsonian Institution, accompanied by W. M. Perrygo, scientific aid, went to Panamá where they were occupied briefly in checking on the fauna on San José Island in the Perlas group, where the Smithsonian made extended studies in 1944. Following this they examined the Canal Zone Biological Area on Barro Colorado Island in Gatún Lake, an agency for which Dr. Wetmore serves as executive officer. They proceeded on March 14, through the assistance of Maj. Gen. H. R. Harmon, Commanding General of the Sixth Air Force, by plane to the auxiliary airfield at Jaqué in eastern Darién. Here they remained until April 16 making detailed collections and studies of the bird life of the coastal area. Ranges of broken hills and the lowlands along the Río Jaqué were a fertile field, so that the 640 specimens obtained during 30 days of field work include representatives of 170 species. These supplement excellently earlier collections under Smithsonian auspices in eastern Darién. The party returned to Washington on April 21.

M. A. Carriker, Jr., traveling under the W. L. Abbott fund of the Smithsonian Institution, this season covered the high páramos of the Sierra Nevada de Santa Marta, Colombia, entering the area in January through San José and San Sebastián de Rábago. Traveling in part with pack oxen, Mr. Carriker worked first at Chinchicuá where there was some forest in addition to the open slopes. At the beginning of February he camped at Simínchucuá at a higher elevation where morning temperatures were frequently near freezing, with ice not uncommon. The next camp called Mamancanaca was at 10,500 feet in a region of glaciated valleys and old moraines. Four lakes at successively higher levels lay below the snow fields at 15,350 feet. Birds in the main were found below 12,000 feet. A further camp was located early in March at 10,000 feet on the headwaters of the Río Guatipurí, and in April still another, farther down the same river at the little Indian hamlet of Chendúcuá. The expedition was highly successful, obtaining fine series of the high-mountain birds, including many not previously represented in the Museum and several that are new to science. Other collections made at lower elevations give representation of the better-known Santa Marta races that make a highly desirable addition to our series from northern Colombia.

In the department of geology Dr. G. A. Cooper, curator of invertebrate paleontology and paleobotany, accompanied by Dr. J. Brookes Knight, research associate, left on June 12 for Austin, Tex., and from there proceeded by auto to the Glass Mountains in west Texas. At that point the party was joined by Dr. R. C. Moore, of the University of Kansas. The three cooperated in collecting blocks of Permian

limestone containing fossils in various parts of the mountains. Dr. Preston E. Cloud joined the party on July 19 and served as leader for further work in the Central Hill country of Texas to collect Mississippian, Devonian, and Pennsylvanian fossils. After a week in this region the party divided, Dr. Moore to return to Kansas and Dr. Cooper and Dr. Knight to join Mrs. J. H. Renfro and Millicent Renfro for four days of collecting in the incomparable Pennsylvanian fossil deposits of Jack County, Tex. Work in the field ended on August 5 after obtaining more than 5 tons of blocks of silicified material to be cleaned by etching with acid, and about 5,000 specimens of invertebrate fossils from central Texas.

On October 1 Dr. Cooper, accompanied by associate curator Byron N. Cooper and Y. Wang, a member of the Geological Survey of China working temporarily at the National Museum, left for the southern Appalachians and the Central Basin of Tennessee. Dr. C. O. Dunbar and Percy Morris of Yale University joined the party at Woodstock, Va. After several days in southwestern Virginia they continued west to Murfreesboro, Tenn., and then to east Tennessee for work near Knoxville. From this vantage point forays were made into various parts of the Ordovician belts of east Tennessee for collecting and study. On October 16 Wang and the two Coopers continued south to Pratts Ferry about 35 miles south of Birmingham, Ala., and from here worked northeast along the Ordovician belts through northeastern Georgia and on into eastern Tennessee and Virginia. The party returned to Washington on November 14. This trip proved most profitable in checking on Ordovician stratigraphy. About 5,000 specimens, including considerable new material, were collected.

On February 7, 1946, Dr. Cooper again left Washington for Austin, Tex., where he joined Dr. Preston E. Cloud, of the Geological Survey, for further studies and collecting in the central hill country. The two visited many localities in the neighborhood of Burnett, San Saba, Mason, and Brady. Many fine Mississippian fossils were collected and Pennsylvanian fossils were also obtained in several places. Dr. Cooper returned to Washington on February 24 with some 5,000 specimens that form a fine representation of these beds.

The Museum's part of the three geological expeditions described above was financed from the income of the Walcott fund.

Dr. C. L. Gazin, curator of vertebrate paleontology, with Franklin Pearce, scientific aid, as assistant, left Washington on May 23, in a truck available through the cooperation of the United States Army, on an expedition into the western States, to obtain additional fossil mammal remains from Paleocene deposits and make further collections of fossil lizards from the Cretaceous in central Utah, as well as

to continue collecting in the Middle Eocene Bridger beds of southwestern Wyoming. These formations have been untouched by collecting parties during the war years and it is expected that weathering will have exposed many additional fossils. The expedition will continue into the next fiscal year, when several fossil localities in the Wind River Basin reported by geological parties of the United States Geological Survey will be investigated. The cooperation of the Army in the loan of the truck is much appreciated since it proved to be a large factor in making the expedition possible. This expedition is another project under the Walcott fund of the Smithsonian Institution.

Dr. W. F. Foshag, curator of mineralogy, spent the first quarter of the year in México concluding field work there, and returned to Washington on October 8. This work on the mineral resources of that country and on Parícutin Volcano was a joint project of the National Museum and the United States Geological Survey in collaboration with the Committee for the Study of Mineral Resources of Mexico. Field studies were completed on the fluorspar deposits of the Tasco District, State of Guerrero, the mercury-copper deposits of Las Fraguas, and the copper deposits of Oropeo, State of Michoacán, with the assistance of Mexican geologists of the committee. Field work in geochemical studies at Parícutin Volcano was continued.

On request from General MacArthur, Dr. Foshag and E. P. Henderson, associate curator in mineralogy, on May 25 went to Tokyo to undertake classification of gem stones under the Army's jurisdiction.

MISCELLANEOUS

Visitors.—An increase of 384,877 visitors to the Museum buildings was recorded over the previous year, the totals being 2,115,593 for 1946 and 1,730,716 for 1945. June 1946 was the month of largest attendance with 246,012 visitors; August 1945 the second largest with 216,801. Records for the four buildings show the following number of visitors: Smithsonian Building, 430,760; Arts and Industries Building, 852,080; Natural History Building, 606,310; Aircraft Building, 226,443.

Publications and printing.—The sum of \$43,000 was allotted the National Museum for its publication and printing requirements for the year 1945–46, the same amount as for the previous year. Of this, \$34,000 was used for printing Bulletins, Proceedings, and Annual Reports; the rest for binding and for the salary of the Museum printer. Thirteen publications were issued—two Annual Reports, six Bulletins, and five Proceedings papers. A list of these is given in the report on publications, appendix 10.

The distribution of volumes and separates to libraries and other institutions and to individuals aggregated 32,887 copies.

Special exhibits.—Eleven special exhibits were held during the year in the foyer and adjacent space of the Natural History Building, under the auspices of various educational, scientific, recreational, and Government groups. In addition, the department of engineering and industries arranged 24 special displays—12 in graphic arts and 12 in photography.

CHANGES IN ORGANIZATION AND STAFF

The end of the war, and the ensuing order of the President directing the Civil Service Commission to resume operations under the civil-service rules, resulted in a considerable number of personnel changes, especially during the transitional period from war-service to probational appointments. During the year several reemployed annuitants, who, with long experience and special qualifications, had remained in active service because of the wartime manpower situation, were retired.

In the department of anthropology, John C. Ewers was appointed associate curator in the division of ethnology on June 3, 1946. Dr. Marshall T. Newman resumed his duties of associate curator in the division of physical anthropology on January 7, 1946, after his release from active military service.

Dr. William R. Maxon, curator, division of plants, retired on May 31, 1946, and was succeeded by Ellsworth P. Killip. On April 30, 1946, Dr. Paul Bartsch, curator, division of mollusks, retired. Other changes in the department of biology were the reappointment, after a wartime furlough to private industry, of Dr. Richard E. Blackwelder, associate curator, division of insects, on November 13, 1945. The department lost by resignation the services of Mrs. Marie P. Fish, scientific aid in the division of fishes, and Mrs. Mildred S. Wilson, assistant curator, division of marine invertebrates, on May 15, 1946, and June 14, 1946, respectively.

The vacancy in the division of vertebrate paleontology caused by the death of Charles W. Gilmore, curator, was filled by the appointment of Dr. Charles L. Gazin on January 21, 1946, and Arlton C. Murray was advanced to scientific aid on March 11, 1946. An addition to the staff of the division of invertebrate paleontology and paleobotany as associate curator was Dr. Alfred R. Loeblich, Jr., on May 31, 1946.

Having been released from active military service, Frank A. Taylor, curator, division of engineering, returned to his duties in the Museum on March 4, 1946. The department of engineering and industries, at

the close of the fiscal year, lost three employees by retirement, as follows: Dr. Frederick L. Lewton, curator, and Mrs. Elizabeth W. Rosson, assistant curator, division of crafts and industries; and Dr. Arthur J. Olmsted, associate curator, section of photography.

Four honorary appointments were made during the year: Dr. Paul Bartsch, associate, division of mollusks; Dr. William R. Maxon, associate in botany; Mrs. Mildred S. Wilson, collaborator in copepod Crustacea; and Dr. J. Brookes Knight, research associate in paleontology.

Under the superintendent of buildings and labor, Walcutt C. Hamer was promoted to assistant mechanical superintendent (foreman of cabinet shop), the position made vacant by the transfer of Rafe A. Watkins to the Army Map Service, and James I. Simpson was assigned the duties of the assistant foreman of cabinet shop effective July 16, 1946. Following retirement for disability on February 20, 1946, of William H. Chism, James C. Clarke was promoted to principal guard (lieutenant), and Edward Zuranski was assigned as principal guard (sergeant) on March 10, 1946. Other additions to the guard officer group were the promotions of Bascom F. Gordon to principal guard (lieutenant) and William H. Baird and Arnold F. Shortridge to principal guards (sergeants) on June 30, 1946.

During the year the following Museum employees returned to their positions after having completed military duty: Edward Zuranski, September 9, 1945; John L. Theunissen and George V. Worthington, October 7, 1945; Charles E. Stousland, November 5, 1945; Joseph Singleton, December 3, 1945; Dr. Charles L. Gazin, December 27, 1945; Clyde E. Bauman, January 2, 1946; Samuel T. Fetterman, January 6, 1946; Dr. Marshall T. Newman, January 7, 1946; Walter McCree, January 30, 1946; Joseph R. Burke, Jr., February 20, 1946; Frank A. Taylor, March 4, 1946; Oliver N. Armstead, March 6, 1946; Robert L. Bradshaw and John Carl Carter, April 1, 1946.

Sixteen persons were retired during the year, under the Civil Service Retirement Act: Through age, Dr. Paul Bartsch, curator, division of mollusks, on April 30, 1946, after 50 years of service; Dr. Frederick L. Lewton, curator, division of crafts and industries, on June 30, 1946, after 34 years 4 months of service; and Dr. Arthur J. Olmsted, associate curator, division of graphic arts, on June 30, 1946, after 26 years 1 month of service. By optional retirement, Dr. William R. Maxon, curator, division of plants, on May 31, 1946, after 46 years 5 months of service; Mrs. Elizabeth W. Rosson, assistant curator, division of crafts and industries, on June 30, 1946, after 33 years 3 months of service; Edgar J. Harrison, mechanic (painter), on August 31, 1945, after 13 years 5 months of service; Augustus G. Lindsay, guard,

on March 31, 1946, after 20 years 6 months of service; Beverly J. Moore, guard, on June 30, 1946, after 3 years 9 months of service; Henry Hicks, laborer, on September 30, 1945, after 23 years 4 months of service, and Mrs. Mary W. Paige, charwoman, on May 31, 1946, after 12 years 3 months of service. Through disability, William H. Chism, lieutenant of guard, on February 20, 1946, after 13 years 10 months of service; Nicola DiGennaro, guard, on July 14, 1945, after 20 years 10 months of service; Leo F. Lennartz, guard, on February 26, 1946, after 5 years 4 months of service; John W. Lockhart, guard on October 15, 1945, after 11 years 3 months of service; Bror O. Olson, guard, on May 31, 1946, after 18 years 1 month of service; and Mrs. Nellie Butler, laborer, on November 30, 1945, after 26 years 11 months of service.

Through death the Museum lost six employees from its active roll during the year: Charles W. Gilmore, curator of vertebrate paleontology, on September 27, 1946, after 41 years 10 months of service; Thomas J. Horne, preparator, on December 26, 1945, after 34 years 9 months of service; George Boylen, mechanic (electrician's helper) on November 28, 1945, after 3 years 9 months of service; Thomas C. Watts, laborer, on October 14, 1945, after 18 years 2 months of service; Roland S. Woodland, laborer, on October 1, 1945, after 11 years of service; and Fannie H. Nedd, laborer, on January 29, 1946, after 12 years of service.

Respectfully submitted.

ALEXANDER WETMORE, *Director.*

THE SECRETARY,
Smithsonian Institution.

APPENDIX 2

REPORT ON THE NATIONAL GALLERY OF ART

SIR: I have the honor to submit, on behalf of the Board of Trustees of the National Gallery of Art, the ninth annual report of the Board, covering its operations for the fiscal year ended June 30, 1946. This report is made pursuant to the provisions of Section 5 (d) of Public Resolution No. 14, Seventy-fifth Congress, First Session, approved March 24, 1937 (50 Stat. 51).

ORGANIZATION AND STAFF

During the fiscal year ended June 30, 1946, the Board consisted of the Chief Justice of the United States, the Secretary of State, the Secretary of the Treasury, the Secretary of the Smithsonian Institution, ex officio, and five general trustees, Samuel H. Kress, Ferdinand Lammot Belin, Duncan Phillips, Chester Dale, and Paul Mellon.

At its annual meeting held on February 11, 1946, the Board reelected Samuel H. Kress as President, and Ferdinand Lammot Belin as Vice President, to serve for the ensuing year. The executive officers continuing in office during the year were:

Huntington Cairns, Secretary-Treasurer.

David E. Finley, Director.

Harry A. McBride, Administrator.

Huntington Cairns, General Counsel.

John Walker, Chief Curator.

Macgill James, Assistant Director.

Donald D. Shepard continued to serve during the year as Adviser to the Board.

During the year Margaret D. Garrett resigned as Chief of the Inter-American Office.

The three standing committees of the Board, provided for in the bylaws, as constituted at the annual meeting of the Board, held February 11, 1946, were:

EXECUTIVE COMMITTEE

Chief Justice of the United States, ex officio, Fred M. Vinson, Chairman.

Samuel H. Kress, Vice Chairman.

Ferdinand Lammot Belin.

Secretary of the Smithsonian Institution, Dr. Alexander Wetmore.

Paul Mellon.

FINANCE COMMITTEE

Secretary of the Treasury, *ex officio*, John W. Snyder, Chairman.
Samuel H. Kress, Vice Chairman.
Ferdinand Lammot Belin.
Paul Mellon.
Chester Dale.

ACQUISITIONS COMMITTEE

Samuel H. Kress, Chairman.
Ferdinand Lammot Belin, Vice Chairman.
Duncan Phillips.
Chester Dale.
David E. Finley, *ex officio*.

The permanent Government positions on the Gallery staff are filled from registers of the United States Civil Service Commission, or with its approval. On June 30, 1946, the permanent Government staff of the Gallery numbered 298 employees, as compared with 245 employees on June 30, 1945; the increase of 53 employees is due chiefly to Public Law 106 (Federal Employees Pay Act of 1945) which placed Government operations on a 40-hour week.

During the past year 21 veterans returned to duty on the Gallery staff, having obtained discharges from the armed forces.

Throughout the year a high standard of operation and maintenance of the Gallery building and grounds and protection of the Gallery's collections of works of art has been sustained.

APPROPRIATIONS

For salaries and expenses for the upkeep and operation of the National Gallery of Art, the protection and care of works of art acquired by the Board of Trustees, and all administrative expenses incident thereto pursuant to the provisions of Section 4 (a) of Public Resolution No. 14, Seventy-fifth Congress, First Session, approved March 24, 1937 (50 Stat. 51), the Congress appropriated for the fiscal year ended June 30, 1946, the sum of \$783,707. This amount includes the regular appropriation of \$583,207, and two supplemental appropriations, one in the sum of \$184,500 required to meet increased pay costs authorized by Public Law 106 (Federal Employees Pay Act of 1945), and the other in the sum of \$16,000, required to cover the costs of within-grade promotions, reallocation of positions, returning veterans, and terminal leave.

From these appropriations the following expenditures and encumbrances were incurred:

Personal services.....	\$661, 187. 45
Printing and binding.....	4, 936. 79
Supplies, equipment, etc.....	117, 256. 77
Unencumbered balance.....	325. 99
Total.....	783, 707. 00

In addition to the above-mentioned appropriations, the Gallery received the sum of \$35,000 from the Department of State to cover expenses during the fiscal year of the Inter-American Office of the Gallery for the promotion of art activities between the United States and the Latin American republics.

The Gallery also received from the War Department an allotment of \$24,000 to be used for the preservation and care of works of art owned by foreign governments which have been placed in temporary custody of the National Gallery of Art.

ATTENDANCE

During the fiscal year 1946, 1,947,668 visitors came to the Gallery building, an average daily attendance of 5,365 people, as compared with 5,711 during 1945, thus showing an annual attendance slightly less than in the previous year. The greatest number of visitors in any one day since the opening of the Gallery was 27,823 on Sunday, October 21, 1945.

The Sunday evening openings, featuring free concerts in the Gallery's East Garden Court, have continued to be exceedingly popular throughout the year.

On May 15, 1946, the Servicemen's Room (Founder's Room), was changed so that it might be used by the general public as a lounge, and it is now in constant use by visitors to the Gallery for writing, reading, and relaxation.

The lifting of travel restrictions since the end of the war has brought a sudden influx of groups of elementary and high school children to view the collections of the Gallery; and during March, April, May, and June of this year 181 groups of young students from the eastern, southern, and midwestern States attended special tours through the Gallery.

PUBLICATIONS

The fiscal year which ended June 30, 1946, saw a considerable expansion in the publishing program of the National Gallery of Art. The second edition of "Masterpieces of Painting from the National Gallery of Art," by Huntington Cairns and John Walker, was placed

on sale on November 1, 1945, and, despite a rise in price made necessary by increased production costs, has continued to sell so well that a third edition is now being printed and a fourth is under discussion.

A catalog entitled "Paintings and Sculpture from the Kress Collection," comprising 200 halftone reproductions, was issued in February 1946, in connection with the opening of the new galleries containing recent additions to the Kress Collection. The National Gallery of Art, the Harvard College Library, and Pantheon Books collaborated in the publication of "Drawings from Ariosto by Fragonard," by Elizabeth Mongan of the Gallery staff, Philip Hofer, and Jean Seznec—a distinguished example both of scholarship and printing. Huntington Cairns, Secretary of the National Gallery of Art, edited a collection of George Saintsbury's essays in a volume entitled "French Literature and Its Masters," published by Alfred A. Knopf in connection with the centenary of Saintsbury's birth.

Articles were published by Huntington Cairns on Sociology and the Social Sciences, in the volume "Twentieth Century Sociology"; The Juristic Bases for International Law, in *Iowa Law Review*, May 1946; A Logician of Science, in *The Sewanee Review*, January 1946; Proust and Painting, in *The Art Bulletin*, March 1946; Methodology of the Social Sciences, in the *University of Chicago Law Review*, December 1945; by John Walker on the protection and salvage of art, in the *National Geographic Magazine*, January 1946; by Fern Rusk Shapley on two paintings in the Gallery's collection in *Gazette des Beaux-Arts*, July 1945, and the *Art Quarterly*, winter 1945.

Mr. Cairns also contributed an article, Philosophy as Jurisprudence, to "Essays in Honor of Roscoe Pound," to be published by Oxford University Press in the fall of 1946. Charles Seymour, Jr., submitted an article to the Henri Focillon memorial issue of the *Gazette des Beaux-Arts* to be published in December 1946. A comprehensive article on the Gallery, its collections, installations, and history was prepared by Joseph Blake Eggen for early publication in *Museion*.

Volumes by members of the Gallery staff in press by the end of the year included "The Limits of Art," by Mr. Cairns, an extensive compilation of selections of poetry and prose that have been held to be the greatest of their kind in critical literature from Aristotle to the present; "Le Chevalier Delibere," with an introduction by Elizabeth Mongan; "Three Centuries of American Painting," by James Lane; and the first of a new series of handbooks, with special reference to the collections of the National Gallery of Art, entitled "The Search for Line," by Lois Bingham, of the educational staff.

Work in preparation for early publication progressed on a book being compiled by Erwin Christensen which will give, under the title "Made in America," an over-all picture of the Index of American De-

sign. Also in preparation for publication were Mr. Walker's monograph on Giovanni Bellini's "Feast of the Gods," in collaboration with Edgar Wind, and a companion volume to "Masterpieces of Painting" on the Gallery's sculpture compiled by Mr. Seymour. Also brought to completion in preparation for publication in the near future was the first of a series of small handbooks on the Widener Collection of decorative arts by Mr. Christensen. Smaller picture books of the Mellon and Widener Collections of paintings and sculpture were also in preparation for publication. For progress on the Gallery catalog, see under Curatorial Department.

Since the Gallery was opened to the public in 1941, well over 2,000,000 postcards of works of art in the Gallery's collections, and more than 400,000 of the Gallery's 11-inch by 14-inch color reproductions have been sold.

The policy of furnishing moderately priced catalogs, color reproductions of fine quality, and other publications, has been continued. Another new edition of the General Information booklet, which is made available to visitors without charge, was issued during the year. Publishers of large collotype reproductions of paintings in the National Gallery of Art have added 15 new titles to their lists during the fiscal year 1946, making a total of 38 of these large reproductions now available.

CONSTRUCTION OF NEW GALLERIES

The contract for the construction of six new gallery rooms, mentioned in the 1945 annual report, was completed during the fiscal year 1946. This construction was carried forward in keeping with the recommendations of the Committee on the Building and a resolution of the Board of Trustees. Three of the rooms are in the east wing of the building and three are in the west wing. These galleries are finished and decorated in a manner similar to the gallery rooms adjacent to them, with the exception of the specially designed room for the exhibition of the Luini panels in the Kress Collection. The work was completed and the galleries were opened to the public on February 2, 1946, for the special opening exhibition of additions to the Kress Collection.

INSTALLATION OF ADDITIONAL AIR-CONDITIONING EQUIPMENT

The gradual opening of additional spaces in the Gallery building and the construction of the six new galleries have made it necessary to augment the air-conditioning equipment in the building by an additional compressor machine. In keeping with recommendations of the Committee on the Building and a resolution of the Board of Trustees,

and with funds donated for the purpose, the Gallery has entered into a contract for the manufacture and installation of this equipment. It is expected that the contract will be completed during the present fiscal year. This fourth compressor machine now being installed will air-condition all the remaining unfinished spaces in the Gallery building.

CUSTODY OF PAINTINGS FROM GERMANY

On December 14, 1945, the late Honorable Harlan Fiske Stone, Chief Justice of the United States and Chairman of the Board of Trustees of the National Gallery of Art, announced that at the request of the Secretary of State, the Trustees of the National Gallery of Art had agreed to accept custody of the 202 paintings from German museums which were to be brought to this country for safekeeping until conditions in Germany insuring their proper care were reestablished. These paintings arrived at the Gallery on December 7, 1945, having been transported to this country with great care by the United States Army; and they are now stored under the custody of the Trustees in the Gallery's air-conditioned storage rooms until they can be returned to Germany. The following is a list of the paintings which are now stored at the Gallery:

<i>Artist</i>	<i>Title</i>
Altdorfer, Albrecht	Departure of the Apostles.
Altdorfer, Albrecht	The Nativity.
Altdorfer, Albrecht	Landscape With a Satyr Family.
Altdorfer, Albrecht	Rest on the Flight Into Egypt.
Amberger, Christoph	The Cosmographer, Sebastian Munster.
Amigoni, Jacopo	Portrait of a Lady as Diana.
Angelico, Fra	Triptych: The Last Judgment.
Antonello da Messina	Portrait of a Young Man.
Austrian c. 1410	The Crucified Christ Mourned by Mary and John.
Austrian c. 1425	The Dead Christ Mourned by Mary and John.
Baldung, Hans (Grien)	Count von Lowenstein.
Baldung, Hans (Grien)	Pyramus and Thisbe.
Baldung, Hans (Grien)	Mourning Over the Body of Christ.
Baldung, Hans (Grien)	Saint George, Saint Catherine.
Baldung, Hans (Grien)	The Adoration of the Magi.
Baldung, Hans (Grien)	Saint Agnes, Saint Mauritius.
Bellini, Giovanni	The Resurrection of Christ.
Bohemian c. 1350	Madonna and Child With Donor.
Bosch, Hieronymus	Saint John on Mount Patmos.
	Reverse: Passion of Christ.
Botticelli, Alessandro	Madonna and Child With Singing Angels.
Botticelli, Alessandro	Simonetta Vespucci.
Botticelli, Alessandro	Giuliano de' Medici.
Botticelli, Alessandro	Saint Sebastian.
Botticelli, Alessandro	Venus.

<i>Artist</i>	<i>Title</i>
Bouts, Dirk-----	Madonna in Adoration.
Bouts, Dirk (?)-----	Madonna and Child.
Bronzino, Angelo-----	Portrait of a Youth.
Bronzino, Angelo-----	Ugolino Martelli.
Bronzino, Angelo-----	Portrait of a Young Man.
Brueghel, Pieter, the Elder-----	Flemish Folk Sayings.
Brueghel, Pieter, the Elder-----	Pair of Fettered Apes.
Burgkmair, Hans-----	The Holy Family.
Caracciolo, Giovanni Battista-----	Two Physicians in the Role of Saint Cos- mas and Saint Damian.
Michelangelo da Caravaggio-----	Conquering Love.
Carpaccio, Vittore-----	Burial of Christ.
Castagno, Andrea del-----	The Ascension of Mary.
Chardin, Jean-Baptiste-Simeon-----	The Draftsman.
Chardin, Jean-Baptiste-Simeon-----	Still Life With Pheasant.
Christus, Petrus-----	Saint Barbara Presents a Carthusian Monk to the Madonna.
Christus, Petrus-----	Lady Talbot.
Joos van Cleve, the Elder-----	Young Man With a Glove.
Cologne c. 1400-----	The Life of Christ.
Cologne c. 1350-----	Diptych: Madonna and Child Enthroned, Crucifixion.
Correggio (Antonio Allegri)-----	Leda and the Swan.
Cossa, Francesco del-----	Allegory of the Harvest.
Cranach, Lucas, the Elder-----	Lucretia.
Cranach, Lucas, the Elder-----	Rest on the Flight Into Egypt.
Cranach, Lucas, the Elder-----	Frau Reuss.
Lorenzo di Credi (?)-----	Portrait of a Young Lady.
Master of the Darmstadt Passion Middle Rhenish-----	The Madonna Enthroned.
Master of the Darmstadt Passion Middle Rhenish-----	Adoration of the Magi.
Master of the Darmstadt Passion Middle Rhenish-----	The Holy Trinity.
Master of the Darmstadt Passion Middle Rhenish-----	Story of the Cross.
Domenico Veneziano-----	Martyrdom of Saint Lucy.
Domenico Veneziano (?)-----	Adoration of the Magi.
Domenico Veneziano (?)-----	Portrait of a Young Lady.
Durer, Albrecht-----	Hieronymus Holzschuher.
Durer, Albrecht-----	Madonna in Prayer.
Durer, Albrecht-----	Madonna With the Siskin.
Durer, Albrecht-----	Portrait of a Young Woman.
Elsheimer, Adam-----	Landscape With Penitent Magdalen.
Elsheimer, Adam-----	The Holy Family with Angels.
Elsheimer, Adam (?)-----	Noah's Thank Offering.
Elsheimer, Adam (?)-----	Saint Christopher.
Eyck, Jan van-----	Giovanni Arnolfini.
Eyck, Jan van-----	Madonna and Child in a Church.
Eyck, Jan van-----	Christ Crucified.
Eyck, Jan van-----	The Man With the Pink.

<i>Artist</i>	<i>Title</i>
Eyck, Jan van.....	Baldwin Delannoy, Knight of the Golden Fleece.
Robert Campin, Master of Flemalle....	The Crucifixion.
Robert Campin, Master of Flemalle....	Portrait of a Man.
Fouquet, Jean.....	Etienne Chevalier and Saint Stephen.
French c. 1400.....	Coronation of Mary.
French c. 1400.....	Diptych: Christ on the Cross. The Man of Sorrows.
Geertgen Tot Sint Jans.....	John the Baptist in the Wilderness.
Geertgen Tot Sint Jans.....	Madonna and Child.
Giorgione.....	Portrait of a Young Man.
Giotto di Bondone.....	Death of Mary.
Giovanni di Paolo.....	The Crucifixion.
Giovanni di Paolo.....	Admission of Saint Clara to a Cloister.
Giovanni di Paolo.....	Saint Clara Aids the Shipwrecked.
Gossaert Jan (Mabuse).....	Christ in the Garden of Gethsemane.
Gossaert Jan (Mabuse).....	Baudouin de Bourbon.
Guardi, Francesco.....	Balloon Ascension on the Giudecca.
Guardi, Francesco.....	The Piazzetta in Venice.
Guardi, Francesco.....	Plaza San Marco, Venice.
Hals, Frans.....	Portrait of a Young Man.
Hals, Frans.....	Portrait of a Young Woman.
Hals, Frans.....	Singing Boy With a Flute.
Hals, Frans.....	Tyman Oosdorp.
Hals, Frans.....	The Witch of Haarlem, Malle Bobbe.
Hals, Frans.....	The Child-Nurse and Her Charge.
Hobbema, Meindert.....	A Road Winding Amongst Clumps of Trees and Small Farms.
Holbein, Hans, the Younger.....	Portrait of an Elderly Man.
Holbein, Hans, the Younger.....	George Gisze.
Holbein, Hans, the Younger.....	Hermann Hillebrandt Wedigh.
Hooch, Pieter de (?).....	The Bugler.
Hooch, Pieter de.....	The Mother.
Kalf, Willem.....	Still Life.
Kalf, Willem.....	Still Life.
Koninck, Philips.....	Panorama of Holland.
La Tour, Georges de.....	Saint Sebastian Mourned by Saint Irene and Her Ladies.
Leyden, Lucas van.....	The Chess Players.
Leyden, Lucas van.....	Madonna and Child with Angels.
Lippi, Filippino.....	Allegory of Music.
Lippi, Fra Filippo.....	The Madonna Adoring the Christ Child.
Lorenzetti, Pietro.....	Saint Humilitas Heals a Sick Nun.
Lorenzetti, Pietro.....	Death of Saint Humilitas.
Lorrain, Claude (Gellee).....	Italian Coastal Landscape in Early Morn- ing Light.
Lotto, Lorenzo.....	Jesus Takes Leave of His Mother.
Mainardi, Sebastiano.....	Portrait of a Young Man With a Red Cap.
Mantegna, Andrea.....	Cardinal Lodovico Mezzarota.
Mantegna, Andrea.....	Presentation in the Temple.
Marmion, Simon.....	Altar of Saint Omer Life of Saint Bertin.

<i>Artist</i>	<i>Title</i>
Marmion, Simon-----	Altar of Saint Omer Life of Saint Bertin.
Martini, Simone-----	The Burial of Christ.
Masaccio-----	Adoration of the Magi.
Masaccio-----	Martyrdom of Saint Peter.
	Martyrdom of Saint John, Baptist.
Masaccio-----	Saint Julian Slays His Parents.
	Saint Nicolas Endows Three Maidens.
Masaccio-----	The Four Saints Predella.
	An Elderly Carmelite.
Masaccio-----	The Four Saints Predella.
	Saint Augustine.
Masaccio-----	The Four Saints Predella.
	Saint Jerome.
Masaccio-----	The Four Saints Predella.
	A Young Carmelite.
Masaccio-----	Felicitations at the Birth of a Florentine of Patrician Family.
Memling, Hans-----	Madonna and Child.
Memling, Hans-----	Madonna and Child.
Memling, Hans-----	Madonna and Child.
Memmi, Lippo-----	Madonna and Child.
Metsys, Quentin-----	The Mourning Magdalen.
Mostaert, Jan-----	Portrait of a Man.
Ouwater, Aelbert van-----	Resurrection of Lazarus.
Palma Vecchio-----	Portrait of a Man.
Palma Vecchio-----	A Young Woman.
Panini, Giovanni Paolo-----	Composite View of the Ruins of Rome.
Patinir, Joachim-----	Rest on the Flight Into Egypt.
Piero di Cosimo-----	Venus, Mars and Amor.
Pollaiuolo, Antonio-----	David With the Head of Goliath.
Poussin, Nicolas-----	The Roman Campagna With Saint Mat- thew and the Angel.
Poussin, Nicolas-----	Jupiter Nourished by the Goat, Amalthea.
Raphael-----	Madonna and Child.
Raphael-----	Madonna and Child With the Little Saint John.
Raphael-----	Madonna and Child With the Little Saint John.
Rembrandt-----	Daniel's Vision.
Rembrandt-----	Hendrikje Stoffels.
Rembrandt-----	Landscape With a Bridge.
Rembrandt-----	The Man With the Golden Helmet.
Rembrandt-----	Moses Breaking the Tablets of the Law.
Rembrandt-----	Old Man With the Red Cap.
Rembrandt-----	Minerva.
Rembrandt-----	Potiphar's Wife Accuses Joseph.
Rembrandt-----	The Preaching of John the Baptist.
Rembrandt-----	Proserpine.
Rembrandt-----	A Rabbi.
Rembrandt-----	Saskia.
Rembrandt-----	Self Portrait.

<i>Artist</i>	<i>Title</i>
Rembrandt.....	Susanna and the Elders.
Rembrandt.....	Tobias and the Angel.
Rubens, Peter Paul.....	Andromeda.
Rubens, Peter Paul.....	Isabella Brandt.
Rubens, Peter Paul.....	Landscape With the Shipwreck of Aeneas.
Rubens, Peter Paul.....	Madonna and Child Enthroned With Saints.
Rubens, Peter Paul.....	Perseus Frees Andromeda.
Rubens, Peter Paul.....	Saint Cecilia.
Ruisdael, Jacob van.....	Haarlem From the Dunes at Overveen.
Sacchi, Andrea (?).....	Alessandro del Borro.
Sassetta.....	Episode From the Legend of Saint Francis.
Sassetta.....	The Mass of Saint Francis.
Schongauer, Martin.....	The Nativity.
Piombo, Sebastiano del (?).....	A Nobleman in the Costume of a Knight of Saint James.
Piombo, Sebastiano del.....	Portrait of a Young Lady of Rome.
Seghers, Hercules.....	View of Rhenen.
Signorelli, Luca.....	Portrait of an Elderly Man.
Signorelli, Luca.....	Saint Catherine of Siena, the Magdalen, and Saint Jerome.
Signorelli, Luca.....	Saints Augustine, Anthony of Padua, Catherine of Alexandria.
Squarcione, Francesco.....	Madonna and Child.
Steen, Jan.....	Baptismal Party.
Steen, Jan.....	The Garden of the Inn.
Strozzi, Bernardo.....	Judith With the Head of Holofernes.
Ter Borch, Gerard.....	The Concert.
Ter Borch, Gerard.....	Fatherly Advice.
Tiepolo, Giovanni Battista.....	Martyrdom of Saint Agatha.
Tiepolo, Giovanni Battista.....	Rinaldo in Armida's Enchanted Garden.
Tiepolo, Giovanni Battista.....	Via Crucis.
Tintoretto, Jacopo.....	Doge Mocenigo.
Tintoretto, Jacopo.....	Portrait of a Man With a Long White Beard.
Titian.....	A Daughter of Roberto Strozzi.
Titian.....	Portrait of a Young Man.
Titian.....	Self Portrait.
Titian.....	Titian's Daughter, Lavinia.
Titian.....	Venus With the Organ Player.
Tura, Cosimo.....	Saint Christopher.
Tura, Cosimo.....	Saint Sebastian.
Velazquez de Silva, Diego.....	Countess Olivares.
Velde, Adriaen van de.....	The Farm.
Vermeer, Jan.....	The Pearl Necklace.
Vermeer, Jan.....	The Taste of Wine.
Verrocchio, Andrea del.....	Madonna and Child.
Verrocchio, Andrea del.....	Madonna and Child.
Master of the Virgo Inter Virgines.....	Adoration of the Magi.
Watteau, Antoine.....	The French Comedians.

<i>Artist</i>	<i>Title</i>
Watteau, Antoine.....	The Italian Comedians.
Watteau, Antoine.....	Outdoor Festival.
Westphalian c. 1250-1270.....	Altarpiece: The Trinity With Mary and Saint John.
Weyden, Rogier van der.....	Charles the Bold, Duke of Burgundy.
Weyden, Rogier van der.....	The Nativity.
Weyden, Rogier van der.....	Augustus and the Tiburtine Sibyl.
Weyden, Rogier van der.....	The Magi.
Weyden, Rogier van der.....	The Saint John Altar. The Life of Saint John.
Weyden, Rogier van der (School of) ..	Joys and Sorrows of Mary.
Weyden, Rogier van der.....	Portrait of a Young Woman.
Witz, Konrad.....	The Decision on the Redemption of Man.
Witz, Konrad.....	The Crucifixion.
Daumier, Honore.....	Don Quixote.
Manet, Edouard.....	The Greenhouse.

ACQUISITIONS

PURCHASE OF PAINTING

On February 11, 1946, the Board of Trustees approved the purchase of the painting, "Siegfried and the Rhine Maidens," by Albert P. Ryder, with funds of the Gallery.

GIFTS OF PAINTING AND SCULPTURE

On October 10, 1945, the Board of Trustees accepted the painting, "Lady with a Harp—(Eliza Ridgely)," by Thomas Sully, from Mrs. Maude Monell Vetlesen. The Board of Trustees on December 7, 1945, accepted the portrait of Aaron Baldwin, by Francis Alexander, from Mrs. Earle E. Bessey, the paintings, "The Johnstone Group," by Sir Henry Raeburn, "Soap Bubbles" and "The Magic Lantern," by Charles-Amedee-Philippe van Loo, from Mrs. Florence S. Schuette, the portrait of Governor Charles Ridgely, by Thomas Sully, from Mr. and Mrs. John Ridgely of Hampton, and the paintings, "A Courtyard, Doge's Palace, with the Procession of the Papal Legate," "A Fete Day, Venice," "The Square of St. Mark's," and "Venice, The Quay of the Piazzetta," by Canaletto, from Mrs. Barbara Hutton. On December 19, 1945, the Board of Trustees accepted the bronze portrait bust, Imaginary Portrait after a Late Roman Bust, by Lodovico Lombardi, from Mr. Stanley Mortimer. On May 10, 1946, the Board of Trustees accepted the portrait of Count Ludovico Vidmano, by Tiberio Tinelli, from Samuel L. Fuller, and on the same date the Board also accepted two bronzes and about half a dozen selected small paintings from George Matthew Adams.

GIFTS OF DECORATIVE ARTS

On December 7, 1945, the Board of Trustees accepted two miniature paintings on porcelain, Louis de Bourbon, Prince de Conde (Le Grand Conde), and Henri Jules, Duc d'Albret (later Prince de Conde), by Jean Petitot, the Elder, from Lessing J. Rosenwald.

GIFTS OF PRINTS AND DRAWINGS

The Board of Trustees, on July 26, 1945, accepted a set of elephant folio of John James Audubon's *Birds of America*, consisting of 435 unbound plates, a set of five volumes of text pertaining to those plates, and miscellaneous letters, clippings, and other papers relating to the plates, from Mrs. Walter B. James. On December 7, 1945, the Board accepted an engraving, "George Town and Federal City or City of Washington," from Otis T. Bradley. On May 10, 1946, the Board accepted a lithograph, "In Memory of the Children of Europe Who Have To Die of Cold and Hunger This Xmas," by Oscar Kokoschka, from Oscar Kokoschka, 17 lithographs from the United States Army Forces, Middle Pacific, a collection of prints, drawings, and etchings by Legros from George Matthew Adams, and a print "L'Heureuse Fecondite," designed by Fragonard and engraved by Nicolas de Launay, from Edwin Wolf, II.

LOAN OF WORKS OF ART TO THE GALLERY

During the fiscal year 1946 the following works of art were received on loan:

<i>Particulars</i>	<i>Artist</i>
From Clarence Y. Palitz, New York, N. Y.:	
The Nymph of the Spring-----	Lucas Cranach the Elder.
From William A. Coolidge, Washington, D. C.:	
View of San Giorgio and the Dogana from	
the Piazza di San Marco-----	Canaletto.
Le Laboureur-----	Vincent van Gogh.
River View at St. Mammes-----	Alfred Sisley.
Landscape on Isle of Wight-----	Joseph Mallord William Turner.
From Mrs. Arthur Iselin and William Jay	
Iselin, Katonah, N. Y.:	
Chief Justice John Jay-----	Gilbert Stuart.
Alexander Hamilton-----	John Trumbull.
From Mrs. Dwight Davis, Washington, D. C.:	
Captain Patrick Miller-----	Sir Henry Raeburn.
From the Army Institute of Pathology, Wash-	
ington, D. C.:	
Dr. John H. Brinton-----	Thomas Eakins.
From Samuel H. Kress and the Samuel H.	
Kress Foundation, New York, N. Y.:	
86 paintings and 12 pieces of sculpture.	

<i>Particulars</i>	<i>Artist</i>
From Madame Charlotte Fuerstenberg, Johannesburg, Africa: 12 French paintings.	
From James Hazen Hyde, New York, N. Y.: Large Brussels tapestry-----	Signed "A. Auwerex."
From Colonel Axel H. Oxholm, Washington, D. C.: Martha Washington-----	Attributed to Ralph Earl.
From Frederick Sturges, Jr., New York, N. Y.: Newport Harbor, 1857-----	John S. Kensett.

LOAN OF WORKS OF ART BY THE GALLERY

During the fiscal year 1946 the Gallery loaned the following works of art for exhibition purposes:

<i>Particulars</i>	<i>Artist</i>
To the George Walter Vincent Smith Art Gallery, Springfield, Mass.: The Lackawanna Valley-----	George Inness.
To the Art Institute of Chicago, Chicago, Ill.: Both Members of This Club-----	George Bellows.
To the Century Association, New York, N. Y.: Portrait of Nathaniel Hawthorne----- Both Members of This Club-----	Emanuel Leutze. George Bellows.
To the Tate Gallery, London, England: Breezing Up----- George Washington----- Mrs. Richard Yates----- The Lackawanna Valley----- Siegfried and the Rhine Maidens----- A Friendly Call----- Governor Charles Ridgely-----	Winslow Homer. Gilbert Stuart. Gilbert Stuart. George Inness. Albert P. Ryder. William Merritt Chase. Thomas Sully.
To the White House, Washington, D. C.: Portrait of George Washington-----	Rembrandt Peale.
To the U. S. Department of State, Blair Lee House, Washington, D. C.: 7 prints from the Rosenwald Collection.	

EXHIBITIONS

The following exhibitions were held at the National Gallery of Art during the fiscal year ended June 30, 1946:

Soldier art. Winning entries in the National Army Arts Contest, sponsored and financed by the Special Services Division, United States Army Service Forces, from July 4 to September 4, 1945.

Currier and Ives prints. Lent by Harry T. Peters, from July 22 to November 25, 1945.

New acquisitions in the Rosenwald Collection. A selection of prints from the new acquisitions in the Rosenwald Collection, from September 9 to November 4, 1945.

Marine Corps battle art. Paintings and sketches made on Pacific battlefields, from Guadalcanal to Okinawa; sponsored and financed by the United States Marine Corps, marking the one hundred and seventieth anniversary of the founding of the Corps, from November 10 to December 16, 1945.

Prints. Selections from the National Gallery's collection of prints and drawings, from November 27, 1945, to March 6, 1946.

Kress additions to the National Gallery of Art. Paintings and sculpture lent to the Kress Collection of the National Gallery of Art by Samuel H. Kress and the Samuel H. Kress Foundation, opening February 2, 1946.

Medicine in prints. A collection formed by Dr. Clements C. Fry of the Department of Health, Yale University, from February 10 to March 24, 1946.

Hogarth and Rowlandson prints. From the Lessing J. Rosenwald Collection, from February 17 to May 19, 1946.

Facsimiles of Russian folk prints. From the Rosenwald Collection, from March 7 to May 13, 1946.

Life of Christ as depicted in the etchings of Rembrandt. Prints from the Rosenwald Collection and an anonymous lender, from May 14, 1946, to continue approximately 2 months.

Audubon prints, "Birds of America." Elephant folio set by John James Audubon, from May 26, 1946, to continue approximately 2 months.

Fine arts under fire. Photographs in 30 panels showing the work of the Monuments and Fine Arts Officers in Europe, from May 14 to June 2, 1946.

I Remember That. Interiors of a generation ago, from a selection of water colors from the Index of American Design, from June 4 to June 16, 1946.

Music in prints. Prints from the Rosenwald Collection, from June 18, 1946, to continue for an indefinite period.

TRAVELING EXHIBITIONS

Index of American Design. Exhibitions from this collection of water colors, drawings, etc., have been shown during the fiscal year 1946 at the following places: University of New Hampshire, Durham, N. H.; Elgin Art Academy Gallery, Elgin, Ill.; Baltimore Museum of Art, Baltimore, Md.; University of Wisconsin, Madison, Wis.; Beauvoir National Cathedral Elementary School, Washington, D. C.; Kanawha County Public Library, Charleston, W. Va.; Society of Liberal Arts, Joslyn Memorial, Omaha, Nebr.; California Palace of the Legion of Honor, San Francisco, Calif.; the Newark Museum, Newark, N. J.; Library of Congress, Washington, D. C.; Ohio State Museum, Columbus, Ohio; American Federation of Arts, Washington, D. C. (for circulation); Antiquarium League of Rochester, N. Y.; American Embassy, Madrid, Spain; and George Washington University, Washington, D. C.

Rosenwald prints. Special exhibitions of prints from the Rosenwald Collection were circulated during the fiscal year 1946 to the following places: Philadelphia Museum of Art, Philadelphia, Pa.; Free Library of Philadelphia, Philadelphia, Pa.; Philadelphia Art Alliance, Philadelphia, Pa.; American British Art Center, New York, N. Y.; Library of Congress, Washington, D. C.; Cayuga Museum of

Art and History, Auburn, N. Y.; Smith College Museum of Art, Northampton, Mass.; and the Inter-American Office of the National Gallery of Art, Washington, D. C., for circulation in South America. Five special exhibitions were held at Alverthorpe Gallery, Jenkintown, Pa., for the Tyler School of Art.

VARIOUS GALLERY ACTIVITIES

During the period from July 1, 1945, through June 30, 1946, a total of 52 Sunday evening concerts were given in the East Garden Court of the Gallery. The concerts were free to the public and were attended by over 50,000 persons. During March 1946, the Third American Music Festival was held and attracted national as well as local interest.

Special suppers for service men and women were held every Sunday night, during the war years, in the staff dining room of the National Gallery of Art. Approximately 7,280 service men and women, many of them in the service of our allies, attended. These suppers, free to the guests, were made possible by generous contributions received from friends and the staff of the National Gallery of Art.

Four additional prints of the 16-mm. sound version of the film, "National Gallery of Art," were acquired, making a total of six prints now owned by the Gallery. Of these, one is now on indefinite loan at the American Embassy in Paris, and a second one was taken by Mr. Walker, Chief Curator of the Gallery, for showing abroad. Prints of the film were borrowed by 13 institutions and individuals for showing.

A total of 136 color reproductions of works of art in the National Gallery have been assembled, labeled, and framed. These reproductions, arranged in sets according to schools, were purchased by the General Federation of Women's Clubs for circulation among its clubs in this country.

A total of 3,235 copies of press releases, 177 special permits to copy paintings in the Gallery, and 86 special permits to photograph in the Gallery were issued.

INDEX OF AMERICAN DESIGN

On July 1, 1945, a new section, staffed by a supervisor and two assistants, was organized to carry out all work connected with the Index of American Design. During the year, the 22,000 drawings were classified and filed. Plans were formulated for lending Index drawings, and in this connection, working contacts have been established with many private individuals, art museums, historical societies, etc. About 20 exhibitions of selected drawings were assembled and circulated. A total of 160 original designs and 66 photographs were selected for

use in connection with publications, and 130 photographs were distributed to artists, manufacturers, research students, etc.

INTER-AMERICAN OFFICE

During the year ended June 30, 1946, the Inter-American Office has continued to carry out the Latin American art program of the Department of State through the exchange of material and publications and the assembling of information on Inter-American art activities. During this time six major photographic exhibitions and two exhibitions of original art were prepared for circulation in Latin America; approximately 300 publications were widely distributed throughout the Latin American countries and a booklet listing *Traveling Exhibitions of Latin American Art in the United States* was compiled, published, and distributed in this country.

CURATORIAL DEPARTMENT

During the past year there were 789 new accessions, either gifts, loans, or deposits, including paintings, sculpture, prints, and the decorative arts. These accessions were registered and the great majority placed on exhibition. Three hundred and seventy works of art were brought to the Gallery for expert opinion, involving 208 consultations. The curatorial staff also made 103 written and 154 verbal replies to questions from the public requiring research, and 23 visits were made to collections of private individuals in connection with offers to the Gallery of gifts or loans. Five members of the staff delivered 21 public lectures on 11 topics.

Work on the revision of the original preliminary catalog, published in 1941, has made considerable progress, and the first portion of the new sculpture catalog, covering Medieval and Renaissance marbles and terra cottas, was completed. At the same time, the cataloging and filing of photographs in the Richter Archive continued, and will be completed within the next year; this will make possible the cataloging and filing of new accessions of photographs without delay as soon as they are received. For the publications of the curatorial staff during the year, see under Publications in this report.

Other important activities of the curatorial staff included the Tate Gallery Exhibition in London, England, which consisted of an exhibition of 220 American paintings, chosen from American museums and private collections for showing in London at the Tate Gallery in June and July. In addition to general organizing responsibilities, Mr. Walker, Chief Curator of the Gallery, was chairman of the committee to select eighteenth- and nineteenth-century paintings.

The curatorial staff continued its assistance to the American Commission for the Protection and Salvage of Artistic and Historic Monuments in War Areas (Justice Owen J. Roberts, Chairman) to the end of the Commission's activity on June 30, 1946.

Although the custodianship of the French Government collection of works of art was terminated February 1, 1945, a number of paintings continued to be housed and exhibited in the National Gallery of Art. At the end of the past fiscal year preparations were begun to remove all but six of those paintings for packing and shipment to France.

RESTORATION AND REPAIR OF WORKS OF ART

With the authorization of the Board and the approval of the Chief Curator, the necessary restoration and repair of works of art in the Gallery's collection were made by Stephen S. Pichetto, Consultant Restorer to the Gallery. All work was completed in the restorer's studio in the Gallery, with the exception of 39 paintings requiring attention before they could be shipped to Washington or on which work had already been begun in Mr. Pichetto's New York studio.

EDUCATIONAL PROGRAM

Approximately 15,000 persons attended the Gallery tours of the collection, and 13,030 attended the lectures in the auditorium by staff and visiting lecturers. The Picture of the Week, a 10-minute, twice-daily talk on a single painting, continued to be a most popular feature, attracting 25,029 persons during the year. Special tours, conferences, and appointments were arranged for 2,599 persons.

LIBRARY

A total of 802 books, 160 pamphlets, and 98 periodicals were presented to the Gallery; 7 books were purchased by the Gallery; 135 photographs and 196 kodachrome slides were presented as gifts; 35 books, 43 pamphlets, and 443 bulletins were received on exchange from other institutions; and 26 subscriptions to periodicals were made; 3,589 books were borrowed and returned, of which number 3,504 were from the Library of Congress and the remaining 85 from art museum and university libraries.

PHOTOGRAPHIC DEPARTMENT

During the year the photographic laboratory of the Gallery made 13,195 prints, 669 black-and-white slides, and 2,026 color slides, in addition to 821 negatives, and 178 X-rays, infrared photographs,

ultraviolet photographs, kodachromes, and sets of color-separation negatives.

OTHER GIFTS

During the fiscal year ended June 30, 1946, gifts of books on art and related material were made to the Gallery by Paul Mellon, Mrs. W. C. Eustis, the Victoria and Albert Museum, Donald D. Shepard, the Dumbarton Oaks Library, the Exchange and Gift Division of the Library of Congress, the educational department of the Young Women's Christian Association, Wells M. Sawyer, and Leander McCormick-Goodhart. Gifts of money during the fiscal year 1946 were received from Mrs. Florence Becker, David E. Finley, Macgill James, Paul Mellon, Duncan Phillips, Lessing J. Rosenwald, and The A. W. Mellon Educational and Charitable Trust.

AUDIT OF PRIVATE FUNDS OF THE GALLERY

An audit is being made of the private funds of the Gallery for the fiscal year ended June 30, 1946, by Price, Waterhouse & Co., public accountants, and the certificate of that company on its examination of the accounting records maintained for such funds will be submitted to the Gallery.

Respectfully submitted.

HUNTINGTON CAIRNS, *Secretary.*

DR. ALEXANDER WETMORE,

Secretary, Smithsonian Institution.

APPENDIX 3

REPORT ON THE NATIONAL COLLECTION OF FINE ARTS

SIR: I have the honor to submit the following report on the activities of the National Collection of Fine Arts for the fiscal year ended June 30, 1946:

APPROPRIATIONS

For the administration of the National Collection of Fine Arts by the Smithsonian Institution, including compensation of necessary employees, purchase of books of reference and periodicals, traveling expenses, and other necessary incidental expenses, \$14,550 was allotted, of which \$5,018.19 was expended in connection with the care and maintenance of the Freer Gallery of Art, a unit of the National Collection of Fine Arts. The balance was spent for the care and upkeep of the National Collection of Fine Arts, nearly all of this sum being required for the payment of salaries, traveling expenses, purchase of books and periodicals, and necessary disbursements for the care of the collection.

THE SMITHSONIAN ART COMMISSION

The twenty-third annual meeting of the Smithsonian Art Commission was held on December 4, 1945. The members assembled in Gallery 3 of the National Collection of Fine Arts, in the Natural History Building, at 10:30 a. m., where, as the advisory committee on the acceptance of works of art which had been submitted during the year, they accepted the following:

Oil painting, *The Woodland Way*, by William Baxter Closson (1848-1926). Gift of the executors of Mrs. Closson's estate.

Oil painting, *Portrait of George Catlin*, by William Fisk, R. A. (1796-1872). Gift of Miss May C. Kinney, Ernest C. Kinney, and Bradford Wickes.

Miniature, *Miss Clementine Dalcour in Mourning*, by A. Margaretta Archambault. Gift of the artist.

Miniature, *Woman Knitting*, by Mary Ursula Whitlock (1860-1944). Gift of the executors of the artist's estate. Accepted for the Smithsonian Institution.

The members then adjourned to the offices of Dr. Wetmore, Secretary of the Institution, for the further proceedings, and the meeting was called to order by the chairman, Mr. Manship.

The members present were: Paul Manship, chairman; Dr. Alexander Wetmore (ex officio); and Robert W. Bliss, John N. Brown, George

H. Edgell, David E. Finley, George H. Myers, Archibald G. Wenley, and Mahonri M. Young. Ruel P. Tolman, Curator of the Division of Graphic Arts in the United States National Museum and Acting Director of the National Collection of Fine Arts, also attended.

The following resolutions on the death of Herbert Adams were submitted and adopted:

Whereas, the Smithsonian Art Commission has learned of the death on May 21, 1945, of Mr. Herbert Adams, a member of the Commission since 1921; therefore be it

Resolved, That the Commission desires here to record its sincere sorrow at the passing of Mr. Adams, an eminent sculptor, whose productions are an enduring monument to his genius. He was ever ready with helpful advice in formulating the policies of the Smithsonian Art Commission and the National Collection of Fine Arts. His helpful interest in the affairs of the Commission will be sadly missed.

Resolved, That these resolutions be spread upon the records of the commission, and that the secretary be requested to inform the family of Mr. Adams of this action.

The resignation of Edward W. Redfield was submitted and accepted with regret. A letter of appreciation for his long and faithful service was ordered sent to him.

The commission recommended to the Board of Regents the name of John Taylor Arms to succeed Mr. Adams, and Eugene E. Speicher to succeed Mr. Redfield.

The following officers were elected for the ensuing year: Paul Manship, chairman; Frank Jewett Mather, Jr., vice chairman, and Dr. Alexander Wetmore, secretary.

The commission recommended to the Board of Regents the reelection of John Nicholas Brown, Mahonri M. Young, George Hewitt Myers, and Robert Woods Bliss for the usual 4-year period.

The following were elected members of the executive committee for the ensuing year: David E. Finley, chairman; Robert Woods Bliss, and Gilmore D. Clark. Paul Manship, as chairman of the Commission, and Dr. Alexander Wetmore, as secretary of the Commission, are ex officio members of the executive committee.

THE CATHERINE WALDEN MYER FUND

Two miniatures, water color on ivory, were acquired from the fund established through the bequest of the late Catherine Walden Myer, as follows:

53. Charles Wm. McGinnes (1793—), by Carl Weinedel (1795–1845); from Mrs. Robert L. Jones, Richland, Wash.

54. Samuel Douchy, by Nathaniel Rogers (1788–1844); from Mrs. Frederic Fairchild Sherman, Millington, N. J.

THE REV. ALFRED DUANE PELL FUND

The following two pieces of pottery were acquired from the fund established through the bequest of the late Rev. Alfred Duane Pell, as follows:

One vase, *Mountains of the Moon*, designed and executed by Lea Halpern, of Holland; from Miss Halpern.

One stoneware bottle, designed and executed by Bernard Leach, of England; from the British Crafts Exhibition.

LOANS ACCEPTED

A marine painting by Lionel Walden (1861–1933), was lent by Admiral Chester W. Nimitz on December 11, and withdrawn on December 21, 1945.

Three miniatures, water color on ivory, Dr. John Austin, of British Guiana, attributed to Alexander Robertson (1772–1841); Jonathan Amory (1802–1885) of Boston, by unknown artist, and Mrs. Jonathan Amory (1806/09–1875), (daughter of Dr. John Austin), by Mme. Busset, were lent by Miss E. M. Matthews of Chevy Chase, Md., on February 14, 1946.

WITHDRAWALS BY OWNERS

A marble bust of Mrs. William C. Preston, by Hiram Powers, lent by James Q. Davis in 1926, was withdrawn by the owner and sent to the University of South Carolina on July 3, 1945.

Three portraits, by Charles Willson Peale, of Mrs. Elliott, Mrs. John O'Donnell, and Mary O'Donnell, and one by Charles Peale Polk of George Washington, lent in 1917, were withdrawn by the owner, Miss Mary Eugenia Parke, on December 17, 1945.

Two pastels, *The Cliffs Aflame*, and *Patsy*, and five oil paintings, *Looking Far Out*, *Joyous Childhood*, *The Red Barn*, *Peonies*, and *Springtime*, by William B. Closson, lent in 1940, were withdrawn by the executors of Mrs. Closson's estate on February 21, 1946.

A silver tankard, lent by Ensign Edward Shippen, United States Naval Reserve, in 1944, was withdrawn by the owner on April 5, 1946.

DEPOSITS

Three bronzes which had been in the art room of the Smithsonian Institution for many years, two entitled *Augustus Caesar*, and the other, *Centaur*, by unknown sculptors, were deposited by the Smithsonian Institution.

LOANS TO OTHER MUSEUMS AND ORGANIZATIONS

Two oil paintings, *Portrait of Commodore Stephen Decatur*, by Gilbert Stuart, and *Portrait of Admiral William S. Sims*, by Irving R. Wiles, were lent to the United States Naval Academy for an exhibition of naval personages and traditions, in connection with the ceremonies held in observing the centennial anniversary of the founding of the United States Naval Academy at Annapolis, on October 10, 1945, held at M. Knoedler & Co., New York City, September 24 through October 13, 1945. (Returned November 6, 1945.)

Two miniatures, *Mrs. Bertha E. Jaques*, by Nelly McKenzie Tolman, and *Woman Knitting*, by Mary Ursula Whitlock, were lent to the Pennsylvania Society of Miniature Painters to be included in their annual exhibition in Philadelphia and Washington. (Returned December 3, 1945.)

An oil painting, *The Visit of the Mistress*, by Winslow Homer, was lent to the Virginia Museum of Fine Arts, Richmond, Va., to be included in their exhibition of Nineteenth Century Virginia Genre Painting, January 17 through February 13, 1946. (Returned February 25, 1946.)

The original design for the painting in the Capitol, *Westward the Course of Empire Takes Its Way*, by Emanuel Leutze, was lent to The Century Association for an exhibition held at their club, New York City, February 7 through March 3, 1946. (Returned March 7, 1946.)

Four water colors by William H. Holmes, *A Maryland Meadow*, *Watt's Branch*, *Near Rockville*, *A Storm-Beaten Coast*, *The Unmodified Rock Creek About 1910*, and *Coal Barge, Capri, 1880*, were lent to The White House, January 25, 1946.

Three oil paintings, *Conway Hills*, by Frederick Ballard Williams, *The Meadow Brook*, by Charles P. Gruppe, and *Sea and Rain*, by George H. Bogert, were lent to the Treasury Department, March 14, 1946, to be hung in the large conference room in the Treasury Building.

Two pastel portraits of Gen. George Washington and Mrs. Martha Washington, by James Sharples, were lent, with the consent of the owners, Mrs. Robert E. Lee, Dr. George Bolling Lee, Mrs. Hanson E. Ely, Jr., and Mrs. William Hunter de Butts, to Knoedler Galleries, New York City, to be included in an exhibition sponsored by the Robert E. Lee Memorial Foundation called "*Stratford Hall, the Lees of Virginia, and Their Contemporaries*," from April 30 to May 18, 1946. (Returned May 27, 1946.)

LOANS RETURNED

One oil painting, *Portrait of Andrew Jackson*, by R. E. W. Earle, lent to the Baltimore Museum of Art, was returned July 21, 1945.

Two oil paintings, *The Woodland Way*, and *Joyous Childhood*, by William Baxter Closson, lent to the civilian medical division, War Department, were returned November 21, 1945.

THE HENRY WARD RANGER FUND

No. 115. *Wreck at Lobster Cove*, by Andrew Winter, N. A. (1893—), purchased in 1940 by the council of the National Academy of Design from the fund provided by the Henry Ward Ranger bequest, was assigned by the council to the Winchester Public Library, Winchester, Mass., December 7, 1945.

The following two paintings were recalled for action on the part of the Smithsonian Art Commission, in accordance with the provision in the Ranger bequest. The Smithsonian Art Commission decided not to accept the paintings and they were returned to the museums to which they were originally assigned:

No. 61. *Woodland Nymph*, by Douglas Volk, N. A. (1856-1935), assigned to the Atlanta Art Association and High Museum of Art, May 16, 1927.

No. 67. *A Long Island Garden*, by Childe Hassam, N. A. (1859-1935), assigned to the Kansas City Art Institute, February 27, 1929.

THE NATIONAL COLLECTION OF FINE ARTS REFERENCE LIBRARY

A total of 414 publications (277 volumes and 137 pamphlets) were accessioned. This number includes 152 volumes and 36 pamphlets purchased, the priced auction catalogs of the Parke-Bernet Galleries accounting for 33 volumes and 30 pamphlets. The other accessions were publications received by exchange, gift, or transfer, with the exception of 72 volumes of periodicals which were returned from the bindery. This year's additions brought the total library accessions to 10,134.

SPECIAL EXHIBITIONS

July 3 through October 9, 1945.—An oil painting, *John Barrymore as Hamlet*, by John Slavin, of Richmond, Va., was shown in Gallery 2.

October 3 through 28, 1945.—The Hon. William D. Pawley collection of 27 portraits of "Flying Tigers," by Raymond P. R. Neilson, N. A., was sponsored by the Chinese Ambassador to the United States, Dr. Wei Tao-Ming. Catalog was privately printed.

October 7 through 28, 1945.—Exhibition of sculptures by Genaro Amador Lira, of Nicaragua, consisting of 11 large pieces, 16 miniature figures carved in wood and ivory and 1 cast in silver, was sponsored by the Pan American Union. A catalog was published by the Pan American Union.

October 8 through 28, 1945.—Twenty portraits of members of the Lafayette Escadrille, and a few other Americans who fought in

World War I, by John Elliott (1858-1925), from our permanent collection.

November 2 through 28, 1945.—The Eighth Metropolitan State Art Contest, held under the auspices of the District of Columbia Chapter, American Artist's Professional League, assisted by the Entre Nous Club. There were 412 exhibits, consisting of paintings, sculpture, prints, and metalcraft.

December 9, 1945, through January 6, 1946.—The forty-fourth annual exhibition of miniatures by the Pennsylvania Society of Miniature Painters, consisting of 100 miniatures. Reprint of catalog.

January 8 through 27, 1946.—Exhibition of 53 portraits by Alfred Jonniaux was held under the patronage of His Excellency, Baron Robert Silvercruys, Belgian Ambassador to the United States. A catalog was published by the artist.

February 1 through 24, 1946.—A Century of the Greeting Card (1846-1946), courtesy of Brownie's Blockprints, Inc., of New York, creators of the Brownie Greeting Cards. There were 136 panels containing 949 cards. A catalog was privately published.

March 1 through 31, 1946.—Exhibition of 53 oil and water-color paintings, by Charles P. Gruppe (1860-1940).

April 5 through 28, 1946.—Exhibition of 54 paintings of Siam by students of the School of Arts and Crafts, Bangkok, held under the auspices of the Royal Siamese Legation.

May 12 through 29, 1946.—Biennial Exhibition of National League of American Pen Women, including 582 art objects.

June 7 through 16, 1946.—Scholastic Calendar Art Competition, sponsored by the Washington Post, including 150 paintings.

Respectfully submitted.

R. P. TOLMAN, *Acting Director.*

DR. A. WETMORE,

Secretary, Smithsonian Institution.

APPENDIX 4

REPORT ON THE FREER GALLERY OF ART

SIR: I have the honor to submit the twenty-sixth annual report on the Freer Gallery of Art for the year ended June 30, 1946.

THE COLLECTIONS

Additions to the collections by purchase were as follows:

BRONZE

- 46.2. Chinese, Han dynasty (206 B. C.-A. D. 220). Gilt bronze cup with plum-colored lacquer overbody, handle in form of a bird's head with jewel eyes and turquoise crest. 0.041 x 0.100 x 0.096.
- 46.4. Chinese, Chou dynasty (1122-256 B. C.). Ceremonial vessel of the type *ting*, smooth bluish-green patina, occasional encrustations of cuprite; two upright inverted U-shaped handles on rim, band of decoration cast in relief around rim; three-character inscription inside. 0.156 x 0.151.
- 46.5. Chinese, Shang dynasty (1766-1122 B. C.). Weapon (ax) of the type *ch'i*; green to gray patina with patches of azurite and cuprite; hole with thickened rim through upper center of blade, decoration cast in relief on *nei*; *nei* and back of blade pierced for hafting; inscription of one character. 0.327 x 0.251; weight: 6- $\frac{3}{4}$ pounds. (Illustrated.)
- 46.8. Chinese, Han dynasty (206 B. C.-A. D. 220). Gilt bronze garment hook in dragon form; back inlaid with 10 pieces of grayish-white to greenish jade; broad piece of jade at back incised with mask pattern. 0.199 x 0.021.
- 46.10. Chinese, Sung dynasty (A. D. 960-1279). Gilt bronze Buddhist image; standing figure of Avalokiteśvara in Yünnanese style; gilding worn in places; figure of Amitābha in headdress; right hand in *vitarka mudrā*, left hand in *vara mudrā*. 0.494 x 0.114.
- 46.11. Chinese, A. D. 6th-7th century. Toilet box with cover: smooth green patina, incised landscape and dragon design on box and cover; quatrefoil and small loop on cover; three ball feet. 0.120 x 0.152.

GOLD

- 46.3. Korean, A. D. 8th-9th century. Headdress ornament, a standing Buddhist image in repoussé relief; surrounded by jeweled glory; 7 of the 19 jewels missing; jewel in *urna* missing; right hand held before breast, left hand pendant holding *māla*. 0.093 x 0.055.

MANUSCRIPT

- 45.41. Chinese, Ming dynasty (A. D. 1368-1644). By Ch'ên Hsien-hsiang (A. D. 1428-1500), a poem of 14 characters in ink on paper; signature of two characters, one seal; part of paper missing at lower edge. 1.834 x 0.915. (Illustrated.)

METALWORK

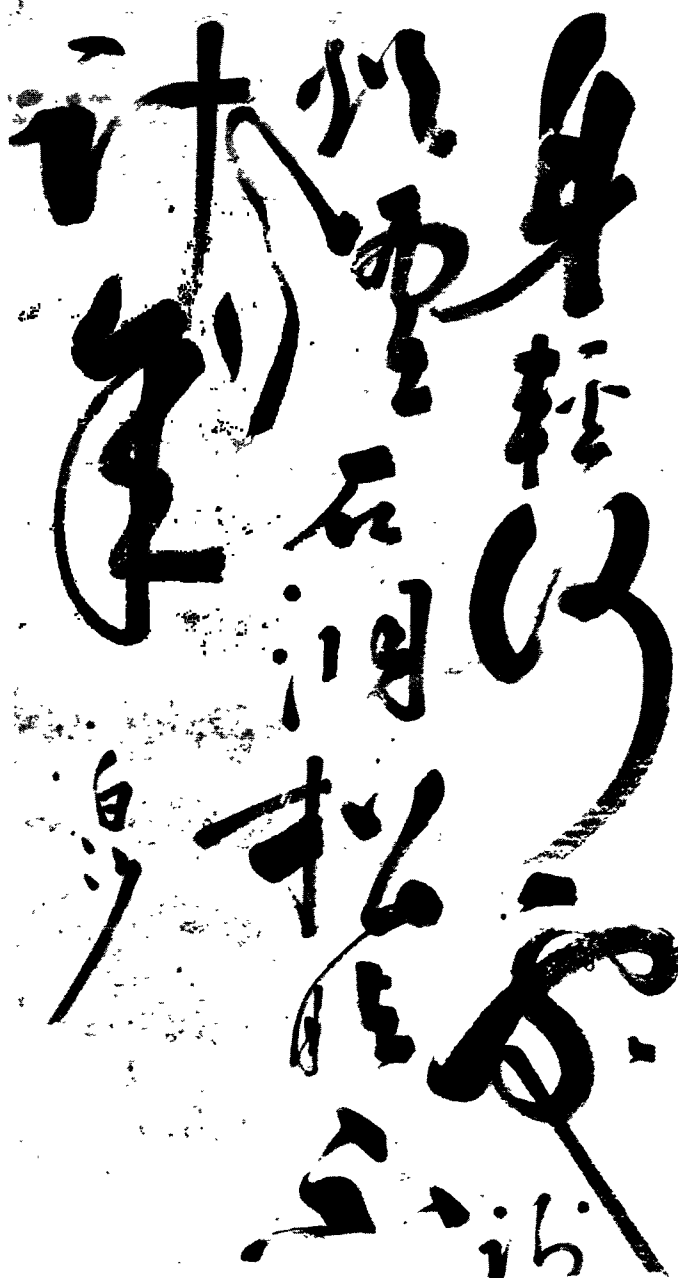
- 45.33. Bactrian, 1st century B. C.-1st century A. D. Bowl (or boss) of thick silver alloy; 12 human figures, a bear, a horse, and an eagle cast in relief on outside, traces of gilding remain. 0.044 x 0.191. (Illustrated.)
- 46.7. Chinese, Han dynasty (206 B. C.-A. D. 220). Iron mirror, much rusted with fragments of original silk container embedded in rust; gold sheet inlaid on back with cut-out figure designs and some repoussé linear designs. Diameter: 0.163.

PAINTING

- 45.33. A recent addition to the collection of the Freer Gallery of Art.
- 45.37. Chinese, Ming dynasty (A. D. 1368-1644). By Sun Chih, dated in correspondence with A. D. 1579. Autumn landscape; ink and color on paper; signature, date and two seals on painting; six seals and five inscriptions on mount. 0.282 x 1.209.
- 45.38. Chinese, Ch'ing dynasty (A. D. 1644-1912). By Chou Hao (A. D. 1685-1773). A landscape in ink on paper; label, signature, six inscriptions and six seals on painting, three inscriptions and nine seals on mount. 0.139 x 3.721.

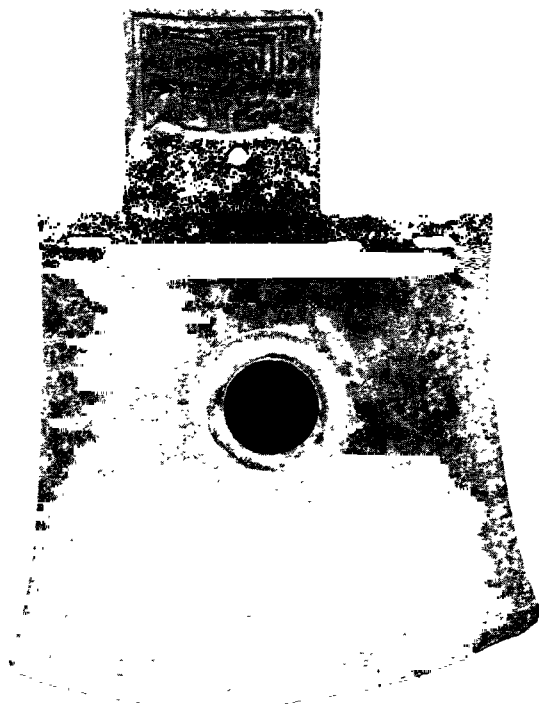
POTTERY

- 45.34. Chinese, Ch'ing dynasty (A. D. 1644-1912). Four-sided vase with animalistic handles, high foot; white porcelain, transparent colorless glaze decorated with overglaze enamels; six-character mark of the Ch'ien-lung period (1736-1796) in underglaze blue on base. 0.272 x 0.192 x 0.121.
- 45.35. Chinese, Ming dynasty (A. D. 1368-1644). Deep, thick-walled bowl; flat ring foot; white porcelain, transparent glaze over underglaze blue decoration; six-character mark of the Hsüan-tê period (1426-1435) in underglaze blue inside bottom. 0.126 x 0.266 (diameter).
- 45.36. Chinese, Ming dynasty (A. D. 1368-1644). Large jar of heavily potted white porcelain, transparent glaze over underglaze blue decoration; two *shou* characters included in design; six-character mark of the Chia-ching period (1522-1567) in underglaze blue on neck. 0.531 x 0.522 (diameter).
- 45.39-
- 45.40. Chinese, Ch'ing dynasty (A. D. 1644-1912). Pair of small bottles with six-lobed bodies and slender cylindrical necks; fine white porcelain covered with transparent glaze very faintly bluish in cast; decorated in underglaze blue and overglaze enamels; six-character mark of the Yung-chêng period (1723-1736) in underglaze blue on bases. 45.39: 0.104 x 0.058; 45.40: 0.105 x 0.058.





45.33



46.5

Recent additions to the collection of the Freer Gallery of Art.

- 46.1. Chinese, Sung dynasty (A. D. 960-1279). Tall vase with cover; southern *Kuan* ware; fine gray clay, thinly potted, glossy bluish green-gray glaze, lightly crackled; decorated with figures in high relief: two tigers, two human figures on shoulder; cloud form with a character incised under the glaze on neck; bird finial and cloud forms on cover. 0.338 x 0.133.
- 46.6. Chinese, Ch'ing dynasty (A. D. 1644-1912). Compound vase formed of a central vase around which five similar forms are attached with internal communication; fine white porcelain, very pale-green transparent glaze; decoration with slip in low relief under glaze; six-character mark of the Ch'ien-lung period (1736-1796) in underglaze blue on base of central vase. 0.165 x 0.140.
- 46.9. Chinese, Sung dynasty (A. D. 960-1279). Vase, *Lung-ch'üan* celadon, bottle-shaped with tall cylindrical neck surrounded by flat horizontal flange ring; fine-grained light-gray porcelain, reddish brown at foot rim; thick, opaque gray-green celadon glaze filled with minute bubbles. 0.165 x 0.072.

The work of the staff members has been devoted to the study of new accessions, of objects submitted for purchase, and to general research work within the collections of Chinese, Japanese, Arabic, Persian, and Indian materials. The preparation of materials for publication and the revision of earlier work has continued. Reports, oral or written, were made upon 1,612 objects and 408 reproductions of objects submitted for examination by their owners, and 132 oriental language inscriptions were translated. Docent service and public lectures given by staff members are listed below.

REPAIRS TO THE COLLECTIONS

A total of 35 objects were repaired or remounted, as follows:

Chinese paintings remounted.....	9
Korean paintings remounted.....	2
Japanese paintings remounted.....	2
Chinese painting repaired.....	1
Chinese album covers repaired and remade.....	5
Arabic painting repaired.....	1
Persian paintings repaired.....	2
Chinese textiles repaired.....	2
Chinese lacquer repaired.....	1
Chinese jades repaired.....	2
Chinese bronze repaired.....	1
Chinese pottery repaired.....	3
Chinese stone sculpture repaired.....	1
Persian pottery repaired.....	1
Arabic manuscript mounted.....	1
Whistler lithograph repaired.....	1

CHANGES IN EXHIBITIONS

Changes in exhibitions totaled 662, as follows:

Chinese arts:

Bamboo carving	4
Bronze	143
Bronze and gold	4
Bronze and jade	16
Gold	2
Gold and iron	4
Jade	183
Marble carving	3
Painting	63
Pottery	101
Silver and silver gilt	28
Wood sculpture	6

Japanese arts:

Lacquer	11
Painting	42
Pottery	36

Korean arts:

Pottery	16
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ATTENDANCE

The Gallery was open to the public from 9 to 4:30 every day except Christmas Day. The total number of visitors to come in the main entrance was 97,822. The weekday total was 65,311, and the Sunday total was 32,511. The average weekday attendance was 203, the average Sunday attendance 626. The highest monthly attendance was in June, with 10,454 visitors; the lowest in December, with 3,874 visitors.

There were 1,625 visitors to the main office during the year; the purposes of their visits were as follows:

For general information	1,074
To see staff members	174
To read in the library	161
To make sketches and tracings from library books	6
To see building and installations	21
To make photographs, sketches, etc., in court	21
To examine, borrow, or purchase photographs and slides	324
To submit objects for examination	354
To see objects in storage:	
<i>Washington Manuscripts</i>	63
Far Eastern paintings and textiles	47
Near Eastern paintings and manuscripts	23
Tibetan paintings	2
Indian paintings and manuscripts	19
American paintings	42
Whistler prints	5

To see objects in storage—Continued.

Oriental pottery, jade, bronze, lacquer, bamboo-----	102
Gold treasure and Byzantine objects-----	4
All sculpture-----	9
Syrian and other glass-----	7
-----	323

DOCENT SERVICE, LECTURES, MEETINGS

By request, 11 groups met in the exhibition galleries for instruction by staff members. Total attendance, 226.

Mrs. Usilton, librarian, gave three talks on indexing before the editors and indexers of the Dewey Decimal Classification System at the Library of Congress, October 23, 26, 30, 1945.

The Freer Gallery of Art auditorium was used for two meetings as follows:

January 12, 1946--The East-West Institute for Librarians. Attendance-- 228

The Director of the Gallery opened the meeting with a brief address of welcome.

May 18, 1946--The Art Technical Section of the American Association of Museums. Attendance----- 150

Members of the staff traveled outside of Washington for professional purposes as follows:

November 13-16, 1945--- Mr. Wenley examined objects at various dealers in New York and attended an evening meeting of the trustees of the Textile Museum of Washington.

December 18, 1945----- Miss Guest and Dr. Ettinghausen spent the day at the Walters Art Gallery in Baltimore studying Near Eastern collections.

February 1, 1946----- Miss Guest spent the day at the University Museum in Philadelphia studying Near Eastern manuscripts.

March 13, 1946----- Mr. Wenley spent the day at Princeton University attending a meeting with Professor Rowley regarding Princeton University Bicentennial, April 1-3, 1947.

April 17-18, 1946----- Dr. Ettinghausen at Princeton University to see Prof. Ernst Herzfeld regarding gift of the Herzfeld Archive to the Smithsonian Institution for deposit in, and under the direction of, the Freer Gallery of Art.

May 31-June 24, 1946--- Dr. Ettinghausen at University of Michigan, Ann Arbor, to do editorial work on *Ars Islamica*.

June 12-14, 1946----- Mrs. Usilton attended annual convention of Special Libraries Association in Boston.

PERSONNEL

Isabel I. Mayer was appointed assistant in research August 1. William R. B. Acker reported for duty December 3, as associate in languages, after serving with the Office of War Information since

December 31, 1942. E. Harriet Link reported for duty as clerk-stenographer (CAF-5), March 18, after completion of her duties as staff aid with the American Red Cross overseas. John A. Pope reported for duty April 22, as associate in research, after completion of his duties as captain, United States Marine Corps Reserve. Grace Dunham Guest, Assistant Director, retired June 30. In recognition of her 26 years of outstanding service, she has been given the honorary title of Freer Gallery of Art research associate.

Respectfully submitted.

A. G. WENLEY, *Director.*

Dr. A. WETMORE,

Secretary, Smithsonian Institution.

APPENDIX 5

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY

SIR: I have the honor to submit the following report on the field researches, office work, and other operations of the Bureau of American Ethnology during the fiscal year ended June 30, 1946, conducted in accordance with the act of Congress of June 27, 1944, which provides “* * * for continuing ethnological researches among the American Indians and the natives of Hawaii and the excavation and preservation of archeologic remains. * * *”

SYSTEMATIC RESEARCHES

Dr. M. W. Stirling, Chief of the Bureau, left Washington January 6, 1946, in order to continue work on the Smithsonian Institution-National Geographic Society archeological project in southern Mexico. From the latter part of January until the middle of April, archeological excavations were conducted at the site of San Lorenzo on the Río Chiquito in southern Veracruz. This was the site discovered by Dr. Stirling the preceding year at the conclusion of the work in Chiapas. During the season's work just concluded a map of the site was completed, several of the mounds were cross-sectioned, and a number of stratigraphic trenches dug.

During the course of the work 24 stone monuments were located, including 5 colossal heads of La Venta type, and 2 table-top altars. In addition, there were a number of miscellaneous monuments representing jaguars and seated figures, both human and anthropomorphic. The collections made during the course of the work, after inspection in Mexico City, were shipped to Washington. During the period of this work, Dr. Stirling was assisted in the field by Dr. Philip Drucker. Dr. Stirling returned to Washington on May 9.

During the fiscal year Dr. Frank H. H. Roberts, Jr., Assistant Chief, read and corrected page proof for the article, “The New World Paleo-Indian,” which was printed in the general appendix to the Annual Report of the Smithsonian Institution for 1944. He prepared an article, “Prehistoric Peoples of Colorado,” to be used as one chapter in a forthcoming history of Colorado which is being published by the State Historical Society of Colorado, and another article, “One Hundred Years of Smithsonian Anthropology,” to be published in

Science. In addition he wrote two book reviews for anthropological journals, annotated six books for the United States Quarterly Book List, and worked on the final report on the investigations at the Lindenmeier-Folsom site.

On the basis of information obtained through correspondence with various members of the Virginia Archeological Society and from a review of the literature on Virginia, Dr. Roberts prepared a statement for the National Park Service, Region 1, on the archeological sites that would be inundated by the construction of dams and reservoirs in the James River Basin, beginning at Richmond and continuing up the main stream and its larger tributaries to the foot of the mountains. He also carried on extensive correspondence in connection with the agreement between the National Park Service and the Smithsonian Institution relative to archeological work in river basins where flood-control dams and irrigation projects will result in the flooding and loss of important archeological sites. This included preliminary plans for work in the Missouri Basin and suggestions and advice on the situation in the Etowah and Savannah River Valleys in Georgia, the Warrior River in Alabama, the Neches, Trinity, and Brazos Rivers in Texas, the Arkansas River and its tributaries in Arkansas and Oklahoma, and the Sacramento, American, Kings, and Kern Rivers in California. This entailed the writing of many letters to local people in the various areas seeking information about the existence of sites and the checking of the literature for additional information. In October Dr. Roberts was designated as director in charge of the archeological surveys and excavations to be conducted under the administration of the Smithsonian Institution in cooperation with the National Park Service, the Corps of Engineers, and the Bureau of Reclamation. In this connection he assisted officials of the National Park Service in preparing estimates and justifications for supplemental funds for 1946 and the funds for 1947 archeological work in the Missouri Basin.

Dr. Roberts also served as the general department representative on the Efficiency Rating Board of Review for the Smithsonian Institution, taking part in three hearings. In relation to this he attended two Civil Service Commission Institutes of Efficiency Rating Boards of Review and six sessions of the Interagency Conference on Training Aids and on Orientation.

On April 12 and 13, 1946, Dr. Roberts represented the Smithsonian Institution at the final convocation and other exercises of the sesquicentennial celebration of the University of North Carolina at Chapel Hill. During the year he also served on various committees for the Institution.

From July 1, 1945, to June 30, 1946, Dr. Roberts served as vice chairman of the division of anthropology and psychology of the National Research Council.

During the absences of the Chief, Dr. Roberts was Acting Chief of the Bureau.

Dr. John P. Harrington, ethnologist, spent the early part of the fiscal year in Washington, D. C., where he produced a Kiowa grammar of 405 manuscript pages and wrote 8 articles for scientific periodicals. During part of this period he was still engaged in work for the Bureau of Censorship.

Dr. Harrington left Washington February 11, 1946, for Clovis, N. Mex. There he interviewed Mr. Scheurich, grandson of Governor Bent, New Mexico's first Governor, and about 80 years of age. From Clovis, Dr. Harrington went directly to Gallup, N. Mex., where he continued his studies of Navaho phonetics. From Gallup he went to Albuquerque, N. Mex., where he worked with Mr. Shupla, expert speaker of the Hano language, which is related to Tewa. From Albuquerque he went to Santa Barbara, Calif., where he continued his Chumashan studies, and was engaged in this work at the close of the fiscal year.

Dr. Henry B. Collins, Jr., ethnologist, resumed his research on Eskimo archeology, which had been largely suspended during recent years because of his duties as Assistant Director, and later Director, of the Ethnogeographic Board. On December 31, 1945, the Board was formally dissolved, but on decision of the sponsoring agencies—the three research councils and the Smithsonian Institution—Dr. Collins continued operation of the office for an additional 6 months. The history of the Ethnogeographic Board, written by Dr. Wendell C. Bennett, was prepared for publication, and a Board project for a survey of wartime Government documents was begun January 1, 1946, under the direction of Dr. Homer G. Barnett, assisted by Walter B. Greenwood. The report on this project has been prepared by Dr. Barnett and will be published, with bibliography, in the near future.

Dr. Collins attended several meetings of the Board of Governors of the Arctic Institute of North America in Montreal, and contributed the section on anthropology for "A Program of Desirable Scientific Investigations in Arctic North America," issued as Bulletin No. 1 of the Arctic Institute. Several book reviews were also prepared for the United States Quarterly Book List and other scientific journals.

As a member of the Committee on International Cooperation in Anthropology of the National Research Council, Dr. Collins assembled from committee records and other sources information on the activities of anthropological societies, universities, and museums in Scan-

dinavia during the war. This was published in the *American Anthropologist* under the title "Anthropology During the War: Scandinavia."

During the month of July 1945, Dr. William N. Fenton was engaged in a study of place names and related activities of the Cornplanter Senecas. When completed, this series, on which M. H. Dear-dorff of Warren, Pa., and C. E. Congdon of Salamanca, N. Y., have collaborated, will comprise the Indian names of places throughout the valley of the Allegheny River. Another problem on which work was continued was the documenting and description of the Condolence Council for installing chiefs in the Iroquois League, the study of which the late J. N. B. Hewitt had commenced a generation ago. Having collected the sacred songs and ritual chants of this ceremony for the Library of Congress in the spring, Dr. Fenton returned to the Six Nations Reserve on October 29, 1945, in the Recording Laboratory sound truck for the purpose of making a documentary film. Dr. Fenton was invited to sit in on the rehearsals and attend the installation of two Cayuga chiefs on November 20, 1945. The family of one of the candidates, Chief John Hardy Gibson, has served American ethnology for two generations, and with the help of Howard Skye and the cooperation of the chiefs, a complete transcript of the proceedings of the Condolence Council among the Canadian Iroquois was prepared and published for the first time since Horatio Hale's account in the last century. This material, written up on returning from the field, became the body of an illustrated lecture on "The Six Nations of Canada," which Dr. Fenton was invited to deliver before the Royal Canadian Institute of Toronto, January 12, 1946. In the field, Ernest Dodge, of the Peabody Museum of Salem, collaborated in recording some rare Iroquois flute music from James White, Onondaga of Six Nations. In addition, a complete performance of the Dark Dance Rite of the Little People was recorded with Eli Jacob, Cayuga of Sour Springs, as leading singer. Similar recordings were made of the Death Feast ritual in the spring, and from Howard Skye, an official of the ceremony, Dr. Fenton obtained a fairly complete account of the fall celebration. The same informant helped translate a Cayuga text of the Tutelo Migration Legend, collected by Hewitt. Returning by way of Allegany Reservation, near Salamanca, N. Y., material for a second album of Iroquois songs was collected from singers at Coldspring Longhouse. Christian hymns in Seneca were recorded near West Salamanca to extend coverage of hymn singing already collected in Mohawk and Oneida. Acknowledgment is due the Viking Fund of New York for support of this field work.

An outstanding event in Iroquois studies was the organization and conduct of the First Conference on Iroquois Research, held October

26-28 at the Allegany State Park, N. Y. Discussions were devoted to ethnology, linguistics, and archeology with reference to the Lower Great Lakes area. The proceedings of the conference, written by Dr. Fenton, were distributed to the 20 persons in attendance and to others interested. Dr. Fenton attended a similar conference on the pre-history of eastern New York and New England, held February 22, 1946, at the New York State Museum, Albany.

"Area Studies in American Universities" reclaimed D. Fenton's attention, when the Commission on Implications of Armed Services Educational Programs, of the American Council on Education, requested him to prepare a report for publication on the Ethnogeographic Board's Survey of the Foreign Area and Language Training Programs of the ASTP and the Civil Affairs Training Schools during 1943-44. The manuscript for the final report, totaling some 180 pages, was virtually completed at the close of the fiscal year. Completion of this report coincided with the end of the Ethnogeographic Board and discharged a final obligation to that wartime activity.

The following publications by Dr. Fenton appeared during the year:

Place names and related activities of the Cornplanter Senecas (Pennsylvania Archaeologist):

III. Burnt-house at Cornplanter Grant, vol. 15, No. 3, pp. 88-96.

IV. Cornplanter Peak to Warren, vol. 15, No. 4, pp. 108-118.

V. The Path to Conewango, vol. 16, No. 2, pp. 42-56.

(With J. N. B. Hewitt) Some mnemonic pictographs relating to the Iroquois Condolence Council (Journal of the Washington Academy of Sciences, vol. 35, No. 10, October 15, 1945, pp. 301-315).

An Iroquois Condolence Council for installing Cayuga chiefs in 1945 (Journal of the Washington Academy of Sciences, vol. 36, No. 4, April 15, 1946, pp. 110-127).

Dr. Philip Drucker, anthropologist, resumed his duties at the Bureau of American Ethnology on December 17, 1945, after release to inactive duty by the Navy. He departed almost immediately for Mexico to assemble equipment, set up camp, and make preparations for excavating a site in southeastern Veracruz, San Lorenzo, that had been selected by Dr. M. W. Stirling, Chief of the Bureau, for this season's work by the National Geographic Society-Smithsonian Institution cooperative expedition. On Dr. Stirling's arrival, in the latter part of January, Dr. Drucker remained as his assistant. Intensive excavations were carried out in various mounds and other features of the site, and numerous stone monuments, including altars, statues, and tremendous monolithic heads of "Olmec" or "La Venta" type were found. While Dr. Stirling occupied himself with a study of the

monuments, Dr. Drucker made tests to locate an occupational zone, and dug a deep stratigraphic trench to obtain ceramic materials to define the culture horizon to which the monuments belong. The material from these investigations will be of inestimable value in tying in the monuments with those of Tres Zapotes and La Venta, and defining the ancient "Olmec" culture.

Following the close of the expedition's camp in mid-April, Dr. Drucker proceeded to the neighboring state of Chiapas to carry out reconnaissance planned to supplement that done by Dr. Stirling the previous year. He was able to locate a number of caves containing offerings or caches of pottery vessels from pre-Spanish times, and made collections which were shipped to Mexico City for ultimate shipment to Washington. In addition to the caves, a number of extensive village sites were discovered which contained not only remains of stone houses but also ball courts and great ceremonial structures of masonry.

On May 21 Dr. Drucker proceeded to Mexico City where the San Lorenzo and Chiapas collections were inspected by officers of the Museo Nacional de Mexico, and where, through the courtesy of those officers, permission was obtained to ship the collections to Washington for study and for preparation of reports for publication. While the shipping permit was going through necessary channels, Dr. Drucker availed himself of the opportunity of studying ceramic and jade collections in the Museo Nacional, and to visit sites in the central highland where important discoveries have been made in recent years, such as Tula, in the state of Hidalgo, and Xochicalco, in Morelos. At the end of the fiscal year he was completing preparations to return to Washington.

During the month of July 1945 Dr. Gordon Willey, anthropologist, was entirely occupied in completing a 50,000-word manuscript entitled "Excavations in Southeast Florida." This paper will make available the results of the archeological field program carried out in south Florida in 1933-36 by the Bureau of American Ethnology in conjunction with the State of Florida.

From August 1945 to February 1946 Dr. Willey was primarily engaged in editorial work on the final volumes of the *Handbook of South American Indians*. The fifth and last volume of this work was submitted to the editor of the Bureau at the end of February, with the exception of part 3, "The languages of South America," which is being prepared by Dr. J. Alden Mason. During this period a 25,000-word article on South American ceramics was prepared for inclusion in the *Handbook*, and a 3,000-word article on the archeology of the Argentine pampas was prepared to be published as part of a Yale University symposium on Argentine archeology.

During the early part of 1946 Dr. Willey also assisted Dr. Roberts in preparing preliminary plans for the Federal Valley Authority archeological program.

In February a brief survey trip was made to Georgia on the proposed Allatoona River control project.

From March until June Dr. Willey was engaged in conducting archeological field work in the Virú Valley in northern Peru, for a proposed study of prehistoric settlement patterns in the valley. At the close of the fiscal year Dr. Willey was still engaged in this field work.

INSTITUTE OF SOCIAL ANTHROPOLOGY

The Institute of Social Anthropology was created in 1943 as an autonomous unit of the Bureau of American Ethnology, to carry out cooperative training in anthropological teaching and research with the other American republics. As the Director, Dr. Julian H. Steward, was instructed in the official order establishing the Institute to report to the Secretary of the Smithsonian Institution; there is presented here his report to Secretary Wetmore.

Washington office.—The Institute of Social Anthropology, carrying out a program of cultural and scientific cooperation with the American republics under a grant of \$77,351 transferred from the Department of State, continued under the directorship of Dr. Julian H. Steward. Miss Ethelwyn Carter served as secretary throughout the year.

Mexico.—In Mexico the Institute was represented by Dr. George M. Foster, Jr., anthropologist, in charge of the work; by Dr. Stanley S. Newman, linguist; and by Dr. Robert C. West, cultural geographer, who joined the staff in February 1946, when Dr. Donald Brand resigned to resume his teaching duties at the University of New Mexico.

Since cooperation with the Escuela Nacional de Antropología began in June 1944, 15 university courses in anthropology, geography, and linguistics have been given, attended by more than 100 individual students. Total enrollment in all courses has exceeded 150. Because of the international nature of the Escuela, it has been possible to reach students from countries other than Mexico, including Haiti, Guatemala, Costa Rica, Panama, Colombia, Spain, France, Canada, and the United States. In both courses and field work, students have had an opportunity to learn American techniques, methodology, and, above all, ideals of scholarship.

Basic field research on the important Tarascan population of Michoacán has been conducted. Institute staff members have put 24 man-months, and the seven participating students 55 man-months, into this research. The field work of the Institute, in conjunction with previous studies, has resulted in the most complete body of cultural

data available on any comparable area in Latin America. One large monograph on the Tarascan area has already been published, and three more will follow in 1947. Six student papers of from 100 to 200 manuscript pages are also being prepared for publication in Spanish by the Escuela.

Peru.—Dr. F. Webster McBryde, cultural geographer, was assigned in September 1945 to take charge of the Institute work in Peru. Harry Tschopik, Jr., continued his work in Peru throughout the year.

The accomplishments can be shown best by a résumé of the work since it began early in 1944. At this time, Peru had no institution devoted essentially to social science teaching and research, and its geographical society was requesting advice from the United States about its proposed reorganization. The cooperation of the Institute has helped the Ministry of Education of Peru to establish a well-financed national center of social science, the Instituto de Estudios Etnológicos. The Instituto, dedicated to teaching, research, and publication, is a most important development, because for the first time Peru can obtain scientific information on her native peoples, who are the predominant element in her contemporary population. The staff of the Peruvian office of the Institute of Social Anthropology has given lectures at the Universities of Cuzco and Trujillo, and courses in geography and anthropology are planned for the Instituto, thus enabling Peruvian students to obtain training in United States techniques of social science. Dr. McBryde has helped in the reorganization of the geographical society and has advised on changes in the geography curriculum in San Marcos University in Lima.

The Institute staff has carried out extensive research among Peruvian coastal and central highland communities. The latter project, done in cooperation with three Peruvian scientists, involved 36 man-months and included 30 different communities. The data will be published in both Spanish and English in several monographs, two of which already are in press. They not only represent significant contributions to knowledge on heretofore little-known groups, but also will be very useful to Peruvian authorities interested in such practical problems as that of obtaining laborers for the high Andean mines and that of colonizing sparsely populated areas of eastern Peru, a matter of prime importance to the agricultural experimental stations. At the request of the Peruvian-Bolivian educational commission, a survey will be made of the settlement patterns of the altiplano to provide a basis for the establishment of rural schools.

The importance of these research results has been acknowledged and stressed by the Minister of Education in a speech before the Peruvian Congress.

Brazil.—Cooperation with the Escola Livre de Sociologia e Politica began October 1, 1945, when Dr. Donald Pierson was assigned as representative of the Institute of Social Anthropology to Brazil. In February 1946, Dr. Kalervo Oberg was assigned as cultural anthropologist to cooperate with the Escola Livre.

In effect, the Institute has taken over and expanded a program which was begun under Dr. Pierson in 1940 and which has helped make the Escola Livre one of the most important social science centers in South America. Seven courses in sociology and anthropology are now being given by the Institute staff. Students in the social science major have increased from 5 in 1945 to 24 in 1946. The first masters degrees in social science were given in February 1946. With the help of the Institute staff, it has been possible to increase the undergraduate curriculum from 3 to 4 years, a very distinct educational gain.

Institute staff members have continued to guide the program of translating 200 articles and 13 books from English into Portuguese. This work, financed by outside funds, is of great importance as an aid to teaching.

Field research to be started this year will meet the outstanding need of Brazilian students, namely, intensive training in field methods through their application. The research results will be published in English and Portuguese. Surveys in Matto Grosso and rural areas near São Paulo have already been carried out by Institute staff members and students.

Publications.—Publication No. 2, "Cherán: A Sierra Tarascan Village," by R. L. Beals, was issued during the year. Publication No. 3, "Moche, a Peruvian Coastal Community," by John Gillin, and Publication No. 4, "Cultural and Historical Geography of Southwest Guatemala," by Felix Webster McBryde, were received in proof. Publication No. 5, "Highland Communities of Central Peru: A Regional Survey," by Harry Tschopik, Jr., was sent to the printer. Publication No. 6, "Empire's Children: Tzintzuntzan and its People," by George M. Foster, Jr., was contracted for by a printer in Mexico. Mrs. Eloise B. Edelen, of the editorial staff of the Bureau of American Ethnology, did the editorial work on these publications.

Handbook of South American Indians.—No grant from the Department of State for cooperation with the American republics was requested for the Handbook during the fiscal year 1946. The final preparation of the manuscript and clerical work pertaining to the Handbook was undertaken by the Washington office of the Institute of Social Anthropology, with the assistance of Dr. Gordon Willey, of the Bureau of American Ethnology.

Volume 1, *The Marginal Tribes*, and volume 2, *The Andean Civilizations*, were issued in June 1946. In addition to the usual edition of 3,500 distributed by the Bureau of American Ethnology, the Department of State ordered 600 copies for distribution through its embassies in Latin American countries, and the Superintendent of Documents ordered 1,000 for sale. Volume 3, *The Tropical Forest Tribes*, and volume 4, *The Circum-Caribbean Tribes*, were received in galley proof. With the exception of the linguistic section, volume 5, *The Comparative Anthropology of South American Indians*, was completed and submitted to the editor of the Bureau of American Ethnology for the final editing.

During the fiscal year, the Interdepartmental Committee on Scientific and Cultural Cooperation of the Department of State granted the Bureau of American Ethnology \$15,000 toward the cost of publishing the Handbook.

SPECIAL RESEARCHES

Miss Frances Densmore, a collaborator of the Bureau, prepared for publication a paper entitled "Music of the Alabama Texas." In this tribe, Miss Densmore found that only ordinary dance songs remain.

She also submitted her complete bibliography covering 50 years of study of American Indian music and a paper entitled "Prelude to the Study of Indian Music in Minnesota." Another long paper was completed on the subject "Distribution of Certain Peculiarities in Indian Songs." This paper is illustrated with a number of distribution maps.

EDITORIAL WORK AND PUBLICATIONS

The editorial work of the Bureau continued during the year under the immediate direction of the editor, M. Helen Palmer. There were issued one Annual Report and one Bulletin, listed below; also two volumes of a five-volume Bulletin, and one publication of the Institute of Social Anthropology.

Sixty-second Annual Report of the Bureau of American Ethnology, 1944-1945. 9 pp.

Bulletin 137. *The Indians of the Southeastern United States*, by John R. Swanton. 943 pp., 108 pls., 5 figs., 13 maps.

The following publications were in press at the close of the fiscal year:

Bulletin 143. *Handbook of South American Indians*. Julian H. Steward, editor. Volume 3: *The Tropical Forest Tribes*. Volume 4: *The Circum-Caribbean Tribes*.

Institute of Social Anthropology Publ. No. 3. Moche, a Peruvian Coastal Community, by John Gillin.

Institute of Social Anthropology Publ. No. 4. Cultural and historical geography of Southwest Guatemala, by Felix Webster McBryde.

Institute of Social Anthropology Publ. No. 5. Highland Communities of Central Peru: A regional survey, by Harry Tschopik, Jr.

Publications distributed totaled 12,730. As compared with the fiscal year 1944-45, this was an increase of 1,160.

In addition to the regular Bureau work, the editorial staff conducted the editorial work on the publications of the Institute of Social Anthropology.

LIBRARY

There has been no change in the library staff during the fiscal year. Accessions during the year totaled 109. There has been a marked falling off in the number of gifts to the library, doubtless due to the disturbed condition of the publishing industry following the end of the war. Though there is a slight decrease in exchange material in the form of books which are entered on the accession book, there has been a very great increase in exchange material as a whole. Large shipments, covering the period since 1939 or 1940 to date, have been received from many of our exchanges in Europe and other parts of the world. Many of our sets have thus been brought up to date without inquiry on our part.

The routine of accessioning and cataloging new material has been kept up to date. A small amount of work has been possible, also, on analytical entries for periodical material. It is hoped that this work will soon be brought up to date.

ILLUSTRATIONS

E. G. Cassedy, illustrator, spent most of his time from July 1945 through April 1946 on art work for the Old Apothecary Shop, a new exhibit in the National Museum. Other work of routine nature was done for the Handbook of South American Indians and for other branches of the Institution.

ARCHIVES

Miss Mae W. Tucker continued her work of operating and cataloging the manuscript and photographic archives of the Bureau. In addition to furnishing material for routine requests for photographs and manuscripts, many qualified visitors were received and furnished with materials or working facilities.

The Mohawk Dictionary, copied by Mrs. Erminnie Smith from records in Canada, was alphabetized and filed for more ready refer-

ence. A number of the Iroquoian vocabularies collected by Mrs. Smith and J. N. B. Hewitt and recorded in the Powell Outline volumes were copied on cards and filed for more convenient reference. The number of these cards so far completed is approximately 7,500. Personal and place names numbering about 600 were copied from New York State historical documents and placed in the card catalog. The Nez Percé dictionary compiled by Miss S. L. McBeth was copied on cards from the original manuscript in the Bureau collection. These cards number about 2,000.

Early in 1946 preparation was begun for a catalog of the unpublished manuscript material in the Bureau archives, to be published for distribution. In order to insure as accurate a catalog as possible the material is being checked piece by piece and listed on memorandum sheets for the final typing.

COLLECTIONS

Collections transferred by the Bureau of American Ethnology to the Department of Anthropology, United States National Museum, during the fiscal year were as follows:

*Accession
No.*

171677. One elk-horn quirt from the Pawnee Indians. Collected about 1877 near Columbus, Nebr., by Elon J. Lawton, M. D.

MISCELLANEOUS

During the course of the year information was furnished by members of the Bureau staff in reply to numerous inquiries concerning the American Indians of both continents, both past and present. Various specimens sent to the Bureau were identified and data on them furnished for their owners.

Personnel.—Dr. Philip Drucker, anthropologist, returned to duty from military furlough on December 17, 1945. Dr. Homer G. Barnett resigned December 31, 1945. Mrs. Catherine M. Phillips, clerk-stenographer, transferred to the War Department May 21, 1945, and Mrs. Jessie S. Shaw was promoted to fill this vacancy effective June 3, 1946, by transfer from the division of ethnology, United States National Museum.

Respectfully submitted.

M. W. STIRLING, *Chief.*

Dr. A. WETMORE,

Secretary, Smithsonian Institution.

APPENDIX 6

REPORT ON THE INTERNATIONAL EXCHANGE SERVICE

SIR: I have the honor to submit the following report on the activities of the International Exchange Service for the fiscal year ended June 30, 1946:

From the appropriation general expenses, Smithsonian Institution, there was allocated at the beginning of the year \$28,166 for the expenses of the Service. After conditions became favorable for the safe transmission to some of the countries where exchanges had been suspended during the war, the Institution requested and was granted a deficiency appropriation of \$17,000. This increased the available appropriation to \$75,166. As it was not possible to make shipments to all the previously suspended countries, the total expenditure amounted to only about \$48,080.25.

The number of packages received for transmission during the year was 540,502, an increase over the previous year of 153,744. The weight of these packages was 472,229 pounds, an increase of 261,139. The average weight of the individual package is almost double that of the previous year—an indication that the institutions are shipping some of the material held during the war. The material is classified as shown in the following table:

	Packages		Weight	
	Sent abroad	Received from abroad	Sent abroad	Received from abroad
United States parliamentary documents sent abroad.....	319, 036		<i>Pounds</i> 127, 863	<i>Pounds</i>
Publications received in return for parliamentary documents.....		2, 267		6, 485
United States departmental documents sent abroad.....	71, 951		75, 935	
Publications received in return for departmental documents.....		4, 043		12, 411
Miscellaneous scientific and literary publications sent abroad.....	122, 708		184, 422	
Miscellaneous scientific and literary publications received from abroad for distribution in the United States.....		20, 497		65, 183
Total.....	513, 695	26, 807	388, 220	84, 079
Grand total.....	540, 502		472, 299	

The packages are forwarded partly by mail direct to the addressees and partly by freight to the exchange bureaus. The number of boxes

shipped abroad was 3,117, an increase of 2,134. Of these boxes, 1,294 were for depositories of full sets of the United States Government documents. The number of packages distributed by mail was 69,833.

Of the material accumulated at the Institution during the war, there remained at the beginning of the fiscal year 3,512 boxes. At the end of the fiscal year this figure had been reduced to 1,109. This reduction was effected through the resumption of exchanges with certain countries where exchange had been suspended during the war. These countries are indicated in the table below by an asterisk.

The countries to which consignments are now regularly forwarded are:

EASTERN HEMISPHERE:

Africa.	*Lebanon.
Australia.	*Netherlands.
*Belgium.	New Zealand.
*Bulgaria.	*Norway.
*China.	*Palestine.
*Czechoslovakia.	Portugal.
*Denmark.	*Spain.
*France.	*Sweden.
Great Britain.	*Switzerland.
*Greece.	*Syria.
India.	Union of Soviet Socialist Republics.
Ireland.	

WESTERN HEMISPHERE: All countries except the United States and her possessions.

Shipments to other countries will be resumed at the earliest practicable date.

FOREIGN DEPOSITORIES OF GOVERNMENTAL DOCUMENTS

The number of sets of United States official publications received to be sent in return for the official publications sent by foreign governments for deposit in the Library of Congress is 93 (56 full and 37 partial sets). The depositories for China and Italy have been changed as indicated in the list.

DEPOSITORIES OF FULL SETS

- ARGENTINA:** Dirección de Investigaciones, Archivo, Biblioteca y Legislación Extranjero, Ministerio de Relaciones Exteriores y Culto, Buenos Aires.
- AUSTRALIA:** Commonwealth Parliament and National Library, Canberra.
- NEW SOUTH WALES:** Public Library of New South Wales, Sydney.
- QUEENSLAND:** Parliamentary Library, Brisbane.
- SOUTH AUSTRALIA:** Public Library of South Australia, Adelaide.
- TASMANIA:** Parliamentary Library, Hobart.
- VICTORIA:** Public Library of Victoria, Melbourne.
- WESTERN AUSTRALIA:** Public Library of Western Australia, Perth.
- BELGIUM:** Bibliothèque Royale, Bruxelles.
- BRAZIL:** Instituto Nacional do Livro, Rio de Janeiro.

CANADA: Library of Parliament, Ottawa.

MANITOBA: Provincial Library, Winnipeg.

ONTARIO: Legislative Library, Toronto.

QUEBEC: Library of the Legislature of the Province of Quebec.

CHILE: Biblioteca Nacional, Santiago.

CHINA: Ministry of Education, National Library, Nanking, China.

PEIPING: National Library of Peiping.

COLOMBIA: Biblioteca Nacional, Bogotá.

COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.

CUBA: Ministerio de Estado, Canje Internacional, Habana.

CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.

DENMARK: Kongelige Danske Videnskabernes Selskab, Copenhagen.

EGYPT: Bureau des Publications, Ministère des Finances, Cairo.

ESTONIA: Riigiraamatukogu (State Library), Tallinn.

FINLAND: Parliamentary Library, Helsinki.

FRANCE: Bibliothèque Nationale, Paris.

GERMANY: Reichstauschstelle im Reichsministerium für Wissenschaft, Erziehung und Volksbildung, Berlin, N. W. 7.

PRUSSIA: Preussische Staatsbibliothek, Berlin, N. W. 7.

GREAT BRITAIN:

ENGLAND: British Museum, London.

LONDON: London School of Economics and Political Science. (Depository of the London County Council.)

HUNGARY: Library, Hungarian House of Delegates, Budapest.

INDIA: Imperial Library, Calcutta.

IRELAND: National Library of Ireland, Dublin.

ITALY: Ministero della Pubblica Istruzione, Rome.

JAPAN: Imperial Library of Japan, Tokyo.

LATVIA: Bibliothèque d'État, Riga.

LEAGUE OF NATIONS: Library of the League of Nations, Geneva, Switzerland.

MEXICO: Secretaría de Relaciones Exteriores, Departamento de Información para el Extranjero, Mexico, D. F.

NETHERLANDS: Royal Library, The Hague.

NEW ZEALAND: General Assembly Library, Wellington.

NORTHERN IRELAND: H. M. Stationery Office, Belfast.

NORWAY: Universitets-Bibliothek, Oslo. (Depository of the Government of Norway.)

PERU: Sección de Propaganda y Publicaciones, Ministerio de Relaciones Exteriores, Lima.

POLAND: Bibliothèque Nationale, Warsaw.

PORTUGAL: Biblioteca Nacional, Lisbon.

RUMANIA: Academia Română, Bucharest.

SPAIN: Cambio Internacional de Publicaciones, Avenida Calvo Sotelo 20, Madrid.

SWEDEN: Kungliga Biblioteket, Stockholm.

SWITZERLAND: Bibliothèque Centrale Fédérale, Berne.

TURKEY: Department of Printing and Engraving, Ministry of Education, Istanbul.

UNION OF SOUTH AFRICA: State Library, Pretoria, Transvaal.

UNION OF SOVIET SOCIALIST REPUBLICS: All-Union Lenin Library, Moscow 115.

UKRAINE: Ukrainian Society for Cultural Relations with Foreign Countries, Kiev.

URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.

VENEZUELA: Biblioteca Nacional, Caracas.

YUGOSLAVIA: Ministère de l'Éducation, Belgrade.

DEPOSITORIES OF PARTIAL SETS

AFGHANISTAN: Library of the Afghan Academy, Kabul.

BOLIVIA: Biblioteca del Ministerio de Relaciones Exteriores y Culto, La Paz.

BRAZIL:

MINAS GERAES: Directoria Geral e Estatística em Minas, Bello Horizonte.

BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara.

CANADA:

ALBERTA: Provincial Library, Edmonton.

BRITISH COLUMBIA: Provincial Library, Victoria.

NEW BRUNSWICK: Legislative Library, Fredericton.

NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.

PRINCE EDWARD ISLAND: Legislative and Public Library, Charlottetown.

SASKATCHEWAN: Legislative Library, Regina.

CEYLON: Chief Secretary's Office, Record Department of the Library, Colombo.

DOMINICAN REPUBLIC: Biblioteca de la Universidad de Santo Domingo, Ciudad Trujillo.

ECUADOR: Biblioteca Nacional, Quito.

GUATEMALA: Biblioteca Nacional, Guatemala.

HAITI: Bibliothèque Nationale, Port-au-Prince.

HONDURAS:

Biblioteca y Archivo Nacionales, Tegucigalpa.

Ministerio de Relaciones Exteriores, Tegucigalpa.

ICELAND: National Library, Reykjavik.

INDIA:

BENGAL: Library, Bengal Legislature, Assembly House, Calcutta.

BIHAR AND ORISSA: Revenue Department, Patna.

BOMBAY: Undersecretary to the Government of Bombay, General Department, Bombay.

BURMA: Secretary to the Government of Burma, Education Department, Rangoon.

PUNJAB: Chief Secretary to the Government of the Punjab, Lahore.

UNITED PROVINCES OF AGRA AND OUDH: University of Allahabad, Allahabad.

IRAN: Imperial Ministry of Education, Tehran.

IRAQ: Public Library, Baghdad.

JAMAICA: Colonial Secretary, Kingston.

LIBERIA: Department of State, Monrovia.

MALTA: Minister for the Treasury, Valletta.

NEWFOUNDLAND: Department of Home Affairs, St. John's.

NICARAGUA: Ministerio de Relaciones Exteriores, Managua.

PANAMA: Ministerio de Relaciones Exteriores, Panama.

PARAGUAY: Ministerio de Relaciones Exteriores, Sección Biblioteca, Asunción.

SALVADOR:

Biblioteca Nacional, San Salvador.

Ministerio de Relaciones Exteriores, San Salvador.

SIAM: Department of Foreign Affairs, Bangkok.

VATICAN CITY: Biblioteca Apostolica Vaticana, Vatican City, Italy.

INTERPARLIAMENTARY EXCHANGE OF THE OFFICIAL JOURNAL

There are now being sent abroad 68 copies of the Federal Register and 63 copies of the Congressional Record. The countries to which these journals are being forwarded are given in the following list:

DEPOSITORIES OF CONGRESSIONAL RECORD AND FEDERAL REGISTER

ARGENTINA:

Biblioteca del Congreso Nacional, Buenos Aires.

Biblioteca del Poder Judicial, Mendoza.²*

Cámara de Diputados, Oficina de Información Parlamentaria, Buenos Aires.

Boletín Oficial de la República Argentina, Ministerio de Justicia e Instrucción Pública, Buenos Aires.

AUSTRALIA:

Commonwealth Parliament and National Library, Canberra.

NEW SOUTH WALES: Library of Parliament of New South Wales, Sydney.

QUEENSLAND: Chief Secretary's Office, Brisbane.

WESTERN AUSTRALIA: Library of Parliament of Western Australia.

BRAZIL:

Biblioteca do Congresso Nacional, Rio de Janeiro.

Imprensa Nacional, Rio de Janeiro.²*

AMAZONAS: Archivo, Biblioteca e Imprensa Publica, Manáos.

BAHIA: Governador do Estado da Bahia, São Salvador.

ESPIRITO SANTO: Presidencia do Estado do Espirito Santo, Victoria.

RIO GRANDE DO SUL: "A Federação," Porto Alegre.

SERGIFE: Biblioteca Publica do Estado de Sergipe, Aracajú.

SÃO PAULO: Imprensa Oficial do Estado, São Paulo.

BRITISH HONDUBAS: Colonial Secretary, Belize.

CANADA:

Library of Parliament, Ottawa.

Clerk of the Senate, Houses of Parliament, Ottawa.

CUBA:

Biblioteca del Capitolio, Habana.

Biblioteca Publica Panamericana, Havana.²*

EGYPT: Ministry of Foreign Affairs, Egyptian Government, Cairo.¹

FRANCE: Bibliothèque du Senat, Paris.

GREAT BRITAIN: Printed Library of the Foreign Office, London.

GREECE: Library, Greek Parliament, Athens.*

GUATEMALA: Biblioteca de la Asamblea Legislativa, Guatemala.

HAITI: Bibliothèque Nationale, Port-au-Prince.

HONDURAS: Biblioteca del Congreso Nacional, Tegucigalpa.

INDIA: Legislative Department, Simla.

ITALY: International Institute for the Unification of Private Law, Rome.²*

IRELAND: Dail Eireann, Dublin.

MEXICO:

Dirección General de Información, Secretaría de Gobernación, Mexico, D. F.

Biblioteca Benjamin Franklin, Mexico, D. F.

*Added during year.

¹ Congressional Record only.

² Federal Register only.

MEXICO—Continued.

AGUASCALIENTES: Gobernador del Estado de Aguascalientes, Aguascalientes.

CAMPECHE: Gobernador del Estado de Campeche, Campeche.

CHIAPAS: Gobernador del Estado de Chiapas, Tuxtla Gutierrez.

CHIHUAHUA: Gobernador del Estado de Chihuahua, Chihuahua.

COAHUILA: Periódico Oficial del Estado de Coahuila, Palacio de Gobierno, Saltillo.

COLIMA: Gobernador del Estado de Colima, Colima.

DURANGO: Gobernador Constitucional del Estado de Durango, Durango.

GUANAJUATO: Secretaría General de Gobierno del Estado, Guanajuato.

GUERRERO: Gobernador del Estado de Guerrero, Chilpancingo.

JALISCO: Biblioteca del Estado, Guadalajara.

LOWER CALIFORNIA: Gobernador del Distrito Norte, Mexicali.

MÉXICO: Gaceta del Gobierno, Toluca.

MICHOACÁN: Secretaría General de Gobierno del Estado de Michoacán, Morelia.

MORELOS: Palacio de Gobierno, Cuernavaca.

NAYARIT: Gobernador de Nayarit, Tepic.

NEW LEÓN: Biblioteca del Estado, Monterrey.

OAXACA: Periódico Oficial, Palacio de Gobierno, Oaxaca.

PUEBLA: Secretaría General de Gobierno, Puebla.

QUERÉTARO: Secretaría General de Gobierno, Sección de Archivo, Querétaro.

SAN LUIS POTOSÍ: Congreso del Estado, San Luis Potosí.

SINALOA: Gobernador del Estado de Sinaloa, Culiacán.

SONORA: Gobernador del Estado de Sonora, Hermosillo.

TABASCO: Secretaría General de Gobierno, Sesión 3a, Ramo de Prensa, Villahermosa.

TAMAULIPAS: Secretaría General de Gobierno, Victoria.

TLAXCALA: Secretaría de Gobierno del Estado, Tlaxcala.

VERACRUZ: Gobernador del Estado de Veracruz, Departamento de Gobernación y Justicia, Jalapa.

YUCATÁN: Gobernador del Estado de Yucatán, Mérida.

NEW ZEALAND: General Assembly Library, Wellington.

PERU: Cámara de Diputados, Lima.

POLAND: Ministry of Justice, Warsaw.¹*

SPAIN: Diputacion of Navarra, San Sebastian.

SWITZERLAND: Biblioteque, Bureau International du Travail, Geneva.²*

UNION OF SOUTH AFRICA:

CAPE OF GOOD HOPE: Library of Parliament, Cape Town.

TRANSVAAL: State Library, Pretoria.

URUGUAY: Diario Oficial, Calle Florida 1178, Montevideo.

VENEZUELA: Biblioteca del Congreso, Caracas.

FOREIGN EXCHANGE AGENCIES

Austria, to which exchanges were formerly sent by way of Germany, has now established her own exchange bureau. Those countries listed below to which exchanges are not yet being sent are: Germany, Japan, Latvia, Rumania, and Yugoslavia. The bureaus whose address has

*Added during year.

² Federal Register only.

changed during the year are marked by an asterisk. The bureaus or agencies listed are those to which consignments are forwarded by freight. To other countries not appearing on the list, packages are sent by mail.

LIST OF AGENCIES

AUSTRIA: Austrian National Library, Vienna.

BELGIUM: Service Belge des Échanges Internationaux, Bibliothèque Royale de Belgique, Bruxelles.

***CHINA:** Bureau of International Exchange, National Central Library, Nanking.

***CZECHOSLOVAKIA:** Bureau des Échanges Internationaux, Bibliothèque de l'Assemblée Nationale, Prague 1-100.

***DENMARK:** Institut des Échanges Internationaux, Bibliothèque Royale, Copenhagen K.

EGYPT: Government Press, Publications Office, Bulaq, Cairo.

FINLAND: Delegation of the Scientific Societies of Finland, Kasängatan 24, Helsinki.

***FRANCE:** Service des Échanges Internationaux, Bibliothèque Nationale, 58 Rue de Richlieu, Paris.

GERMANY: Amerika-Institut, Universitätstrasse 8, Berlin, N. W. 7.

GREAT BRITAIN AND IRELAND: Wheldon & Wesley, 721 North Circular Road, Willesden, London, N. W. 2.

HUNGARY: Hungarian Libraries Board, Ferenciektere 5, Budapest, IV.

INDIA: Superintendent of Government Printing and Stationery, Bombay.

***ITALY:** Ufficio delgi Scambi Internazionali, Ministero della Pubblica Istruzione, Rome.

JAPAN: International Exchange Service, Imperial Library of Japan, Uyeno Park, Tokyo.

LATVIA: Service des Échanges Internationaux, Bibliothèque d'État de Lettonie, Riga.

NETHERLANDS: International Exchange Bureau of the Netherlands, Royal Library, The Hague.

NEW SOUTH WALES: Public Library of New South Wales, Sydney.

NEW ZEALAND: General Assembly Library, Wellington.

NORWAY: Service Norvégien des Échanges Internationaux, Bibliothèque de l'Université Royale, Oslo.

PALESTINE: Jewish National and University Library, Jerusalem.

POLAND: Service Polonais des Échanges Internationaux, Bibliothèque Nationale, Warsaw.

PORTUGAL: Secção de Trocas Internacionais, Biblioteca Nacional, Lisbon.

QUEENSLAND: Bureau of Exchanges of International Publications, Chief Secretary's Office, Brisbane.

RUMANIA: Ministère de la Propagande Nationale, Service des Échanges Internationaux, Bucharest.

SOUTH AUSTRALIA: South Australian Government Exchanges Bureau, Government Printing and Stationery Office, Adelaide.

SPAIN: Junta de Intercambio y Adquisición de Libros y Revista para Bibliotecas Públicas, Ministerio de Educación Nacional, Avenida Calvo Sotelo 20, Madrid.

SWEDEN: Kungliga Biblioteket, Stockholm.

*SWITZERLAND: Service Suisse des Échanges Internationaux, Bibliothèque Centrale Fédérale, Palais Fédérale, Berne.

TASMANIA: Secretary to the Premier, Hobart.

TURKEY: Ministry of Education, Department of Printing and Engraving, Istanbul.

UNION OF SOUTH AFRICA: Government Printing and Stationery Office, Cape Town, Cape of Good Hope.

UNION OF SOVIET SOCIALIST REPUBLICS: International Book Exchange Department, Society for Cultural Relations with Foreign Countries, Moscow, 56.

VICTORIA: Public Library of Victoria, Melbourne.

WESTERN AUSTRALIA: Public Library of Western Australia, Perth.

YUGOSLAVIA: Section des Échanges Internationaux, Ministère des Affaires Étrangères, Belgrade.

Frank E. Gass, correspondence clerk, who had been for several years Acting Chief Clerk of Exchanges, retired on June 30, after almost 60 years of service. Mr. Gass was appointed as messenger on August 1, 1886, and retired in March of 1941. When the manpower situation became acute in 1942 Mr. Gass returned to the Exchanges to serve during the war.

D. G. Williams was appointed as Chief Clerk on February 25.

Carl E. Hellyer, on January 11, was transferred from the guard force to the position of shipping clerk.

Glenn P. Shephard, on March 4, was transferred from the Freer Gallery of Art to the Exchanges and detailed to the Government Document Room.

Harold Peacock, after honorable discharge from the Signal Corps of the United States Army, was employed by the Institution on April 2, and detailed to the incoming mail room in charge of records and geographic distribution.

Respectfully submitted.

H. W. DORSEY, *Acting Chief.*

Dr. A. WETMORE,

Secretary, Smithsonian Institution.

APPENDIX 7

ANNUAL REPORT ON THE NATIONAL ZOOLOGICAL PARK

SIR: I have the honor to submit the following report on the operations of the National Zoological Park for the fiscal year ended June 30, 1946:

The appropriation for the regular operations of the Zoo was \$310,000. A supplemental appropriation of \$65,670 for salary increases authorized by Congress was also made available, making a total of \$375,670. Subject to minor changes in final bills, a total of \$359,453 was expended for all purposes and an unexpended balance of \$16,217 remains. This balance was due to the difficulty in filling vacant positions and in obtaining materials.

Reconversion to a peacetime set-up is proving to be a slow process involving much effort in selecting, training, and orienting new employees. However, substantial progress has been made in recruiting personnel, although a number of vacancies still exist including some in skilled positions which could not be quickly filled. The additional manpower taken on was largely offset by reduction in working hours from 48 to 44 or 40 hours a week. As rapidly as possible, all units of the organization are being put on the 40-hour week.

The problem of obtaining materials such as building supplies and others used in the maintenance of structures has continued to be very difficult. Indeed, some supplies have been more difficult to obtain than they were during the wartime. It has nevertheless been possible to improve some of the structures in the Park and to do some clean-up work that had been neglected during the war. Therefore, by the close of the fiscal year there was a perceptible improvement in the general conditions throughout the entire establishment.

NEEDS OF THE ZOO

A small addition to the personnel is needed to enable the Zoo to carry on the work in an efficient manner and permit employees to take the leave to which they are legally entitled. The Zoo has been undermanned throughout the entire period of its existence, and with the adoption of the 40-hour week, the situation has been particularly acute.

Of no less importance is the need for new buildings to replace antiquated, dilapidated structures that are still used to house animals.

Preliminary planning has been taken up with the Public Works Administration for construction of these buildings when economic conditions justify.

A great deal of general maintenance and improvement work must be done to restore the Park and structures to a presentable condition. With a moderate increase in personnel the improvements can be gradually effected as materials become available.

VISITORS

With the removal of the ban on pleasure driving and in line with the general increase in traveling, there has been a marked increase in number of visitors, particularly those from more distant States, as well as in traveling groups and school groups.

ESTIMATED NUMBER OF VISITORS FOR FISCAL YEAR 1946

July (1945).....	169,600	February.....	129,950
August.....	271,000	March.....	215,900
September.....	247,700	April.....	381,137
October.....	264,000	May.....	169,700
November.....	151,100	June.....	260,900
December.....	42,850		
January (1946).....	68,500	Total.....	2,372,337

The attendance for the fiscal year 1945 was given in the last annual report as 2,355,514, whereas it should have been 2,107,084. Therefore, the actual increase in attendance in 1946 is 265,253.

NUMBER OF GROUPS FROM SCHOOLS

	Number of groups	Number in groups		Number of groups	Number in groups
Alabama.....	1	17	New Jersey.....	21	1,376
Connecticut.....	3	140	New York.....	8	957
Delaware.....	5	210	North Carolina.....	15	700
District of Columbia.....	60	2,719	Ohio.....	21	551
Georgia.....	12	319	Pennsylvania.....	104	4,024
Illinois.....	1	34	South Carolina.....	19	599
Kentucky.....	4	173	Tennessee.....	6	236
Maine.....	4	246	Virginia.....	115	5,795
Maryland.....	172	10,829	West Virginia.....	9	513
Massachusetts.....	8	488			
Michigan.....	3	84	Total.....	592	30,062
New Hampshire.....	1	52			

About 2 p. m. each day the cars then parked in the Zoo are counted by the Zoo police and listed according to the State, Territory, or country from which they came. This is, of course, not a census of cars coming to the Zoo but is valuable in showing the percentage of attend-

ance by States of people in private automobiles. The tabulation for the fiscal year 1946 is as follows:

	Percent		Percent
Washington, D. C.-----	27.7	Ohio-----	1.6
Maryland-----	26.2	North Carolina-----	1.5
Virginia-----	10.7	New Jersey-----	1.3
Pennsylvania-----	3.9	Massachusetts-----	1.00
New York-----	2.9	Florida-----	1.05

The cars that made up the remaining 22.06 percent came from every one of the remaining States, as well as from the following Territories and countries: Alaska, Alberta, British Columbia, Canal Zone, Cuba, Mexico, New Brunswick, Nova Scotia, Ontario, Peru, Philippine Islands, Prince Edward Island, Puerto Rico, and Quebec.

It is well known that District of Columbia, Maryland, and Virginia cars bring to the Zoo many people from other parts of the United States and of the world, but no figures are available on which to base percentages.

THE EXHIBITS

The total number of individual animals and the different kinds of animals the Zoo has been able to maintain during the war has not declined as much as was anticipated, although the variety of rare, unusual, or especially interesting animals has been reduced, the reduction being offset in part by more of the commoner creatures. At the beginning of the war, when it appeared that Washington might be bombed, the Zoo disposed of its venomous snakes. Later, when the danger of bombing was over, several lots of the interesting pit viper known as habu (*Trimeresurus flavoviridis*) were kept for the Army Medical Corps which was using them in connection with some of their studies.

As rapidly as possible under present conditions the Zoo is endeavoring to build up the collection to the prewar standard. Because of restrictions on transportation few live animals are being brought into this country, but it is anticipated that this condition will gradually improve.

The Park's collection of alligators, crocodiles, and caimans is outstanding in that it includes 11 different species which are listed later in this report.

The birth of a baby Arabian oryx (*Oryx leucoryx*) was highly gratifying, but unfortunately after a few days the little one died, although it seemed to be in perfect condition and there was no clue as to the cause of its death.

Other rarities such as the pigmy galago or "bush baby," pottos, and burrowing pythons were received directly from West Africa, rare frogs were flown from South America and Panama, two pairs of quetzals were received from Costa Rica and several cocks-of-the-rock from South America. From the New York Zoological Society the Park received three very large Galapagos tortoises that had been collected while young many years ago and raised in Florida. Small and attractive cage birds, not imported during the war, are coming in again, and a considerable number of species have been added to the collection.

ACQUISITION OF SPECIMENS

Additions of specimens of the Zoo collection were by gifts, deposits, purchase, and births or hatchings.

DEPOSITORS AND DONORS AND THEIR GIFTS

Adams, Donald, Washington, D. C., 2 Pekin ducks.
 Alexander, W. F., Silver Spring, Md., 4 Pekin ducks.
 Allentuck, Lester, Washington, D. C., Philippine macaque.
 Aquarium, Department of Commerce, Washington, D. C., alligator.
 Ballou, George, Bethesda, Md., bassariscus, ribbon snake. 4 racers, 4 rattlesnakes
 Bandy, Billy, Wayne, Maine, 30 garter snakes.
 Beck, J. S., Washington, D. C., snapping turtle.
 Bernstein, Eddie, Washington, D. C., white-throated capuchin.*
 Bessinger, J. M., Washington, D. C., 4 Cumberland terrapins.
 Bianco, Mrs. L. O., Washington, D. C., Pekin duck.
 Botts, L. J., Washington, D. C., barred owl.
 Botts, Max, Hampton, Va., green guenon.
 Bowen, Felix, Bethesda, Md., capuchin.*
 Bozeivich, Lucal, Berwyn, Md., 2 goats.
 Breeding, Charles R., Washington, D. C., 2 Pekin ducks.
 Brill, W. J., Jr., Washington, D. C., Cooper's hawk.*
 Brown, Col. F. Q., Bethesda, Md., brown-cheeked parrot.
 Buck, Congressman Ellsworth B., Washington, D. C., 45 frogs.*
 Busey, Bill, Washington, D. C., Pekin duck.
 Capley, J. B., Baltimore, Md., green guenon.
 Carmichael, Michel, Washington, D. C., 2 Pekin ducks.
 Carr, Commander B. L., Washington, D. C., snake-head fish.
 Carter, Dr. Hill, Washington, D. C., great horned owl.*
 Casbarian, James P., Washington, D. C., great horned owl.
 Caspar, J. A., Washington, D. C., green guenon.
 Chapman, Mr. and Mrs. Otto, Silver Spring, Md., whistling swan.
 Chick, W. J., Jr., and Fowler, J. A., National Park Service, Washington, D. C., hog-nosed snake.
 Cohen, Mrs. Roger, Chevy Chase, Md., 5 guinea pigs, 25 mice.
 Colburn, Norman C., Washington, D. C., 6 rabbits.
 Cooke, Lt. Jay, Baltimore, Md., 50 xenopus frogs.*

*Deposits.

Cookston, Maj. R. E., Lakewood, Ohio, yellow-headed parrot.*
Cooper, Suzanne T., Washington, D. C., 2 barbs, 3 zebra fish, 2 South American catfish.
Crenshaw, Joel, Arlington, Va., Pekin duck.
Denis, Armand, Dania, Fla., green mamba, black mamba.
District of Columbia Health Department, Washington, D. C., 3 rhesus monkeys.*
District of Columbia Police, through Officer E. M. Brown, Washington, D. C., black-crowned night heron.
Duncan, C. H., Greenbelt, Md., 2 Pekin ducks.
Earnest, E. P., Washington, D. C., black widow spider.
Erlanger, Arlene, Washington, D. C., palm tanager, gouldian finch.
Ewart, Jack, Washington, D. C., red coatimundi.*
Fairchild, Dr. Graham, Gorgas Memorial Library, Canal Zone, 3 frogs.
Faller, Erwin H., Washington, D. C., corn snake.
Ford, Robert W., Alexandria, Va., black vulture.
Garret, J., Rappahannock Academy, Va., red fox.
Gatti, Stephen, Washington, D. C., great horned owl.
Gleason, Martin A., Washington, D. C., king snake.
Gould, Louise, Washington, D. C., false chameleon.
Graham, Mrs. W. W., Washington, D. C., 2 grass paroquets.*
Haakinson, E. B., Washington, D. C., garter snake.
Hall, Mrs. Frank, Washington, D. C., 2 Pekin ducks.
Hall, Mary, Alexandria, Va., 2 red squirrels.
Hamlet, John N., Washington, D. C., red salamander, 15 pine or fence lizards, 6 blue-tailed skinks, prairie falcon, black vulture, Alleghany wood rat, 3 whip-tailed lizards, scorpion.
Hanby, Mrs. B. F., Arlington, Va., yellow-headed parrot.
Harder, Mrs. Arthur, Washington, D. C., 2 ring-necked doves.
Hayes, Mrs. M. M., Washington, D. C., sparrow hawk.
Headley, Mrs. Wharton, Kinsale, Va., bald eagle.
Helfrick, W. G., Washington, D. C., sparrow hawk.
Hohlen, Mae, Washington, D. C., sparrow hawk.
Hottel, W. H., Tegucigalpa, Honduras, long-tailed spotted cat.
Hugg, Mary, Washington, D. C., alligator.
Humphrey, Don, Washington, D. C., barn owl.
Huppmann, Louis B., Baltimore, Md., scaup.
Hust, Gye, Washington, D. C., Pekin duck.
Ingham, Rex, Ruffin, N. C., scarlet king snake, coatimundi,* bare-eyed cockatoo.*
Jones, Cullen, Cheverly, Md., red salamander.
Jones, Henry J., Bethesda, Md., Jersey cow.
Jones, William, Washington, D. C., raccoon.
Katsuranus, Joseph, Washington, D. C., alligator.
Kelley, James Ford, Jr., Silver Spring, Md., opossum.
Kelley, W. J., Silver Spring, Md., opossum.
Knudtsen, Einar B., Baltimore, Md., 2 water snakes.
Lane, John G., Washington, D. C., skunk.
LaVarre, William, Washington, D. C., 2 American crows.
Lepphard, Charles, Washington, D. C., fence lizard.
Link, Cornelius, Washington, D. C., chicken snake.
Lond, Mrs. Wendell, Washington, D. C., 3 Pekin ducks.

*Deposits.

Lynch, Mrs. J. O., Bethesda, Md., Pekin duck.
 Major, Frederick G., Arlington, Va., 4 horned lizards.
 Mann, Mrs. C. R., Washington, D. C., tufted titmouse.
 Mannix, Mrs. Dan, Washington, D. C., red fox.
 Mannix, Lieut. D. P., Washington, D. C., bald eagle, rabbit.
 Mayer, Lieut. John, Washington, D. C., sparrow hawk.
 McCarthy, F., Washington, D. C., sparrow hawk.
 McLanahan, Duer, Washington, D. C., Pekin duck.
 Medical Corps, U. S. Army, 31 habu vipers, 3 water snakes, akamatah.
 Meems Brothers and Ward, Long Island, New York, 2 Cape cobras.
 Meikle, Mrs. J. C., Washington, D. C., grass paroquet.
 Melvin Dairy, Washington, D. C., northern porcupine.
 Meredith, Florence, Arlington, Va., double yellow-headed parrot.
 Miles, Jay, Takoma Park, Md., white squirrel.
 Millard, C. C., Washington, D. C., 2 rabbits.
 Minker, H. L., Washington, D. C., Pekin duck.
 Morgan, David, Bethesda, Md., red-shouldered hawk.*
 Needham, P. H., Washington, D. C., Pekin duck.
 Neri, Joseppe, Washington, D. C., golden pheasant.
 Netherland, Frank, Kenwood, Md., 2 Pekin ducks.
 Newill, Dr. D. S., Connellyville, Pa., hybrid jungle fowl, gray jungle fowl.*
 New York Zoological Society, through John TeeVan, 3 Galapagos tortoises.*
 Nida, Robert, Washington, D. C., sparrow hawk.
 O'Dwyer, Arthur, Washington, D. C., horned lizard.
 Old, W. E., Williamston, N. C., 5 DeKay's snakes, 4 blue-tailed skinks, marbled salamander, 2 gray frogs, milliped, 10 ground skinks.
 Parker, Harry Lamont, Montevideo, Uruguay, 30 Stelzner's frogs.
 Penney, Mrs., Colesville, Md., 2 raccoons.
 Phillips, C. E., Kensington, Md., Pekin duck.
 Poiley, S. M., National Institute of Health, Washington, D. C., 4 meadow mice.
 Preston, P. D., Silver Spring, Md., canary.
 Putziger, Bernard, Arlington, Va., 2 Pekin ducks.
 Pyle, George L., Arlington, Va., opossum and 8 young.
 Rafferty, J. P., Arlington, Va., 2 alligators.
 Randall, H. W., Washington, D. C., Florida diamond-backed rattlesnake, cotton-mouthed moccasin, black snake, western bull snake, pilot black snake.
 Reamy, J. L., Washington, D. C., 2 rabbits.
 Redfield, David, Washington, D. C., chipmunk.
 Rehe, Mrs., Arlington, Va., Pekin duck.
 Richards, Henry, Washington, D. C., white-throated capuchin.*
 Runnels, Ormond, Arlington, Va., blue jay.
 Santlemann, Mrs. W. F., Arlington, Va., 2 Pekin ducks.
 Schmid, Ed, Washington, D. C., 50 tiger salamanders.
 Schneider, Mildred, Washington, D. C., 3 rabbits.
 Scott, Mary, Arlington, Va., Pekin duck.
 Shaw, H. L., Baltimore, Md., Hamadryas baboon.*
 Shelby, Lizzie, Hillside, Md., bull snake, 3 hog-nosed snakes, 2 garter snakes, 2 water snakes, green racer.
 Smith, David A., Chevy Chase, Md., mallard duck.
 Smith, Douglas P., Bethesda, Md., rabbit.
 Smith, Mr. and Mrs. Leslie, Vienna, Va., 6 mallard ducks, 2 Pekin ducks, skunk.

*Deposits.

Smith, Spencer, Orange, Fla., 2 gray foxes.
 Stabler, Albert, Jr., Spencerville, Md., ground hog, red jungle fowl.
 Steele, Mrs. S. F., Chevy Chase, Md., 2 Pekin ducks.
 Stiller, Bertram, Washington, D. C., flying squirrel.
 Tate, R. D., Seat Pleasant, Md., red fox.
 TeeVan, John, Miami, Fla., 3 Galapagos tortoises.*
 Theadore, Mrs. John, Washington, D. C., rabbit.
 Thomas, Miss, Bradley, Va., Pekin duck.
 Thomas, Maj. W. B. S., U. S. Army, Mexican water snake, 3 worm snakes,
 2 lizards, 9 akamatahs.
 Thompson's Dairy, Washington, D. C., horned lizard.
 Trueblood, Winslow, Cohasset, Mass., wood turtle.
 Turner, Bill, Westwood, Prince Georges County, Md., duck hawk.
 Ulke, Dr. Titus, Washington, D. C., spade-footed toad.
 Vermillion, Mrs., Washington, D. C., skunk.*
 Wesley, Rhoda, Washington, D. C., red salamander, opossum.
 Westburg, Leroy, Washington, D. C., hog-nosed snake.
 White, Vivian, Washington, D. C., blue-fronted parrot.
 Woolf, D. O., Washington, D. C., 2 black widow spiders.
 Wyatt, Archie, Washington, D. C., guinea pig.

BIRTHS AND HATCHINGS

MAMMALS

<i>Scientific name</i>	<i>Common name</i>	<i>Number</i>
<i>Ammotragus lervia</i>	Aoudad.....	5
<i>Axis axis</i>	Axis deer.....	2
<i>Bibos gaurus</i>	Gaur.....	1
<i>Bison bison</i>	American bison.....	2
<i>Bos indicus</i>	Zebu.....	1
<i>Bos taurus</i>	Park cattle.....	1
<i>Camelus bactrianus</i>	Bactrian camel.....	1
<i>Cercopithecus aethiops sabaeus</i>	Green guenon.....	1
<i>Cervus canadensis</i>	American elk.....	1
<i>Chinchilla chinchilla</i>	Chinchilla.....	3
<i>Choeropsis liberiensis</i>	Pigmy hippopotamus.....	1
<i>Cynomys ludovicianus</i>	Plains prairie dog.....	15
<i>Dama dama</i>	Fallow deer.....	2
<i>Dama dama</i>	White fallow deer.....	4
<i>Dasyprocta punctata</i>	Spectacled agouti.....	1
<i>Felis tigris</i>	Bengal tiger.....	6
<i>Hippopotamus amphibius</i>	Hippopotamus.....	1
<i>Odocoileus virginianus</i>	Virginia deer.....	1
<i>Oryx leucoryx</i>	Arabian oryx.....	1
<i>Ovis aries</i>	Woolless sheep.....	2
<i>Ovis europaeus</i>	Mouflon.....	1
<i>Sika sika</i>	Sika deer.....	1
<i>Synceros caffer</i>	African buffalo.....	1
<i>Thalarctos maritimus</i>	Polar bear.....	1
<i>Thalarctos maritimus</i> × <i>Ursus middendorffi</i>	Hybrid bear.....	2

*Deposits.

BIRTHS AND HATCHINGS—continued

BIRDS

Scientific name	Common name	Number
<i>Anas platyrhynchos</i>	Mallard duck.....	15
<i>Branta canadensis</i>	Canada goose.....	2
<i>Larus novae-hollandiae</i>	Silver gull.....	3
<i>Taeniopygia castanotis</i>	Zebra finch.....	11
<i>Taeniopygia castanotis</i>	Zebra finch (gray phase).....	3
<i>Turtur risorius</i>	Ring-necked dove.....	17

REPTILES

<i>Epicrates cenchris</i>	Rainbow boa.....	23
<i>Gekko gekko</i>	Gecko.....	2

AMPHIBIANS

<i>Pipa americana</i>	Surinam toad.....	26
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ANIMALS IN THE NATIONAL ZOOLOGICAL PARK, JUNE 30, 1946

MAMMALS

MARSUPIALIA

Scientific name	Common name	Number
Didelphidae:		
<i>Didelphis virginiana</i>	Opposum.....	11
Phalangeridae:		
<i>Petaurus breviceps</i>	Lesser flying phalanger.....	2
<i>Petaurus norfolcensis</i>	Australian flying phalanger.....	2
Macropodidae:		
<i>Dendrolagus inustus</i>	New Guinea tree kangaroo.....	2
<i>Thylogale eugenii</i>	Dama wallaby.....	4
Phascolomyidae:		
<i>Vombatus ursinus</i>	Flinders Island wombat.....	1

CARNIVORA

Felidae:

<i>Acinonyx jubatus</i>	Cheetah.....	1
<i>Felis chaus</i>	Jungle cat.....	1
<i>Felis concolor</i>	Puma.....	5
<i>Felis concolor patagonica</i>	Patagonian puma.....	1
<i>Felis concolor</i> × <i>Felis concolor patagonica</i>	Hybrid North American × South American puma.....	4
<i>Felis leo</i>	Lion.....	5
<i>Felis onca</i>	{ Jaguar.....	4
	{ Black jaguar.....	2
<i>Felis pardalis</i>	Ocelot.....	2
<i>Felis pardus</i>	{ Indian leopard.....	3
	{ Black Indian leopard.....	2
<i>Felis temmenckii</i>	Golden cat.....	2
<i>Felis tigris</i>	Bengal tiger.....	2
<i>Felis tigris longipilis</i>	Siberian tiger.....	1

MAMMALS—continued

CARNIVORA—continued

Scientific name	Common name	Number
Felidae—Continued		
<i>Felis tigris sumatrae</i> -----	Sumatran tiger-----	3
<i>Lynx rufus</i> -----	Bay lynx-----	2
<i>Lynx uinta</i> -----	Bob cat-----	1
<i>Oncifelis geoffroyi</i> -----	Geoffroy's cat-----	4
<i>Oncilla pardinoidea</i> -----	Lesser tiger cat-----	2
Viverridae:		
<i>Arctictis binturong</i> -----	Binturong-----	1
<i>Civettictis civetta</i> -----	African civet-----	1
<i>Myonax sanguineus</i> -----	Dwarf civet-----	1
<i>Nandinia binotata</i> -----	West African palm civet-----	1
<i>Paradoxurus hermaphroditus</i> -----	Small-toothed palm civet-----	2
Hyaenidae:		
<i>Crocuta crocuta germinans</i> -----	East African spotted hyena-----	1
Canidae:		
<i>Canis latrans</i> -----	Coyote-----	1
<i>Canis latrans</i> × <i>familiaris</i> -----	Coyote and dog hybrid-----	1
<i>Canis lupus nubilus</i> -----	Plains wolf-----	2
<i>Canis niger rufus</i> -----	Texas red wolf-----	3
<i>Cuon javanicus sumatrensis</i> -----	Sumatran wild dog-----	1
<i>Dusicyon culpaesus</i> -----	South American fox-----	1
<i>Dusicyon (Cerdocyon) thous</i> -----	South American fox-----	1
<i>Nyctereutes procyonoides</i> -----	Raccoon dog-----	2
<i>Urocyon cinereoargenteus</i> -----	Gray fox-----	5
<i>Vulpes fulva</i> -----	Red fox-----	10
Procyonidae:		
<i>Nasua narica</i> -----	Coatimundi-----	11
<i>Nasua nasua</i> -----	Red coatimundi-----	1
<i>Nasua nelsoni</i> -----	Nelson's coatimundi-----	2
<i>Potos flavus</i> -----	Kinkajou-----	7
<i>Procyon lotor</i> -----	{ Raccoon-----	6
	{ Black raccoon-----	8
	{ Raccoon (albino)-----	1
Bassariscidae:		
<i>Bassariscus astutus</i> -----	Ring-tail or cacomistle-----	1
Mustelidae:		
<i>Grison</i> sp-----	Grison-----	1
<i>Grisonella huronae</i> -----	Grison-----	1
<i>Lutra canadensis vaga</i> -----	Florida otter-----	1
<i>Lutra (Micraonyx) cinerea</i> -----	Small-clawed otter-----	1
<i>Martes (Lamprogale) flavigula henrici</i> -----	Asiatic marten-----	1
<i>Meles meles leptorhynchus</i> -----	Chinese badger-----	1
<i>Mellivora capensis</i> -----	Ratel-----	1
<i>Mephitis mephitis nigra</i> -----	Skunk-----	11
<i>Mustela eversmanni</i> -----	Ferret-----	1
<i>Mustela frenata noveboracensis</i> -----	Weasel-----	1
<i>Tayra barbara barbara</i> -----	White tayra-----	2
<i>Tayra barbara senilis</i> -----	Gray-headed tayra-----	1

MAMMALS—continued

CARNIVORA—continued

Scientific name	Common name	Number
Ursidae:		
<i>Euarctos americanus</i>	Black bear.....	4
<i>Euarctos thibetanus</i>	Himalayan bear.....	1
<i>Helarctos malayanus</i>	Malay or sun bear.....	1
<i>Melursus ursinus</i>	Sloth bear.....	1
<i>Thalarctos maritimus</i>	Polar bear.....	3
<i>Thalarctos maritimus</i> × <i>Ursus middendorffi</i>	Hybrid bear.....	4
<i>Ursus arctos</i>	European brown bear.....	1
<i>Ursus arctos meridionalis</i>	Caucasus brown bear.....	1
<i>Ursus gyas</i>	Alaskan Peninsula bear.....	3
<i>Ursus middendorffi</i>	Kodiak bear.....	3
<i>Ursus sitkensis</i>	Sitka brown bear.....	3

PINNIPEDIA

Otariidae:		
<i>Zalophus californianus</i>	Sea lion.....	3
Phocidae:		
<i>Phoca vitulina richardii</i>	Pacific harbor seal.....	2

PRIMATES

Lemuridae:		
<i>Galago demidovii</i>	Least galago.....	1
<i>Lemur mongoz</i>	Mongoose lemur.....	2
<i>Perodicticus potto</i>	Potto.....	3
Callitrichidae:		
<i>Callithrix jacchus</i>	White-tufted marmoset.....	1
<i>Leontocebus rosalia</i>	Lion-headed or golden marmoset.....	1
<i>Oedipomidas geoffroyi</i>	Geoffroy's marmoset.....	1
Cebidae:		
<i>Aotus trivirgatus</i>	Douroucoulis or owl monkey.....	4
<i>Ateles geoffroyi vellerosus</i>	Spider monkey.....	9
<i>Cebus apella</i>	Gray capuchin.....	5
<i>Cebus capucinus</i>	White-throated capuchin.....	3
<i>Cebus fatuellus</i>	Weeping capuchin.....	2
<i>Lagothrix lagotricha</i>	Woolly monkey.....	1
Cercopithecidae:		
<i>Cercocebus albigularis</i>	Blue monkey.....	1
<i>Cercocebus atterimus</i>	Black-crested mangabey.....	1
<i>Cercocebus torquatus atys</i>	Sooty mangabey.....	2
<i>Cercocebus torquatus lunulatus</i>	White-crowned mangabey.....	1
<i>Cercopithecus aethiops pygerythrus</i>	Vervet guenon.....	2
<i>Cercopithecus aethiops sabaenus</i>	Green guenon.....	8
<i>Cercopithecus cephus</i>	Moustached guenon.....	2
<i>Cercopithecus diana</i>	Diana monkey.....	3
<i>Cercopithecus diana roloway</i>	Roloway monkey.....	2
<i>Cercopithecus neglectus</i>	De Brazza's guenon.....	1
<i>Cercopithecus nictitans petaurista</i>	Lesser white-nosed guenon.....	2

MAMMALS—continued

PRIMATES—continued

<i>Scientific name</i>	<i>Common name</i>	<i>Number</i>
Cercopithecidae—Continued		
<i>Cercopithecus</i> sp.....	West African guenon.....	1
<i>Erythrocebus patas</i>	Patas monkey.....	1
<i>Gymnopyga maurus</i>	Moor monkey.....	1
<i>Macaca irus mordax</i>	Javan macaque.....	4
<i>Macaca mulatta</i>	Rhesus monkey.....	8
<i>Macaca nemestrina</i>	Pig-tailed monkey.....	2
<i>Macaca philippinensis</i>	Philippine macaque.....	5
<i>Macaca silene</i>	Wanderoo monkey.....	2
<i>Macaca sinica</i>	Toque or bonnet monkey.....	1
<i>Macaca speciosa</i>	Red-faced macaque.....	1
<i>Mandrillus sphinx</i>	Mandrill.....	1
<i>Papio comatus</i>	Chacma.....	1
Hylobatidae:		
<i>Hylobates agilis</i>	Sumatran gibbon.....	1
<i>Hylobates agilis</i> × <i>Hylobates lar pileatus</i>	Hybrid gibbon.....	1
<i>Hylobates hoolock</i>	Hoolock gibbon.....	1
<i>Hylobates lar pileatus</i>	Black-capped gibbon.....	1
<i>Symphalangus syndactylus</i>	Siamang gibbon.....	1
Pongidae:		
<i>Pan troglodytes</i>	Chimpanzee.....	2
<i>Pan troglodytes verus</i>	West African chimpanzee.....	2
<i>Pongo pygmaeus</i>	Bornean orangutan.....	1
<i>Pongo pygmaeus abelii</i>	Sumatran orangutan.....	2
RODENTIA		
Sciuridae:		
<i>Callosciurus flayaysoni</i>	Lesser white squirrel.....	1
<i>Citellus beecheyi douglasii</i>	Douglas ground squirrel.....	4
<i>Citellus tridecemlineatus</i>	13-lined ground squirrel.....	1
<i>Cynomys ludovicianus</i>	Plains prairie dog.....	40
<i>Funisciurus leucostigma</i>	West African bush squirrel.....	3
<i>Glaucomys volans</i>	Flying squirrel.....	14
<i>Heliosciurus rufobrachium maculatus</i>	West African sun squirrel.....	1
<i>Marmota monax</i>	Woodchuck or ground hog.....	5
<i>Ratufa indica</i>	Giant Indian squirrel.....	1
<i>Sciurus aberti</i>	Abert's squirrel.....	1
<i>Sciurus niger neglectus</i>	Fox squirrel.....	1
<i>Tamias striatus</i>	Eastern chipmunk.....	2
Heteromyidae:		
<i>Dipodomys ordii</i>	Ord kangaroo rat.....	3
Cricetidae:		
<i>Cricetomys gambianus</i>	Gambia pouched rat.....	1
<i>Mesocricetus auratus</i>	Golden hamster.....	4
<i>Microtus magister</i>	Meadow mouse.....	2
<i>Neotoma floridana attwateri</i>	Round-tailed wood rat.....	2
<i>Neotoma pennsylvanica</i>	Allegheny wood rat.....	1
<i>Oryzomys palustris</i>	Rice rat.....	2
<i>Peromyscus crinitus auripectus</i>	Golden-breasted mouse.....	1

MAMMALS—continued

RODENTIA—continued

<i>Scientific name</i>	<i>Common name</i>	<i>Number</i>
Cricetidae—Continued		
<i>Peromyscus leucopus</i>	White-footed or deer mouse.....	1
<i>Sigmodon hispidus</i>	Cotton rat.....	3
Muridae:		
<i>Mus musculus</i>	White and other domestic mice.....	13
Hystriidae:		
<i>Acanthion brachyurum</i>	Malay porcupine.....	3
<i>Atherurus africanus</i>	West African brush-tailed porcupine.....	3
<i>Thecurus crassispinis sumatrae</i>	Thick-spined porcupine.....	1
Myocastoridae:		
<i>Myocastor coypus</i>	Coypu.....	7
Cuniculidae:		
<i>Cuniculus paca virgatus</i>	Central American paca.....	1
Dasyproctidae:		
<i>Dasyprocta prymnolopha</i>	Agouti.....	2
<i>Dasyprocta punctata</i>	Speckled agouti.....	4
Chinchillidae:		
<i>Chinchilla chinchilla</i>	Chinchilla.....	8
Caviidae:		
<i>Cavia porcellus</i>	Guinea pig.....	3
<i>Dolichotis patagona</i>	Patagonian cavy.....	1

LAGOMORPHA

Leporidae:		
<i>Oryctolagus cuniculus</i>	Domestic rabbits.....	5
<i>Sylvilagus floridanus</i>	Eastern cottontail rabbit.....	1

ARTIODACTYLA

Bovidae:		
<i>Ammotragus lervia</i>	Aoudad.....	15
<i>Anoa fergusonii</i>	Mountain anoa.....	1
<i>Bibos gaurus</i>	Gaur.....	3
<i>Bison bison</i>	{ American bison.....	13
	{ Albino bison.....	1
<i>Bos indicus</i>	Zebu.....	4
<i>Bos taurus</i>	Domestic cow (Jersey).....	1
<i>Bos taurus</i>	Texas longhorn steer.....	1
<i>Bos taurus</i>	West Highland or KYloe cattle.....	3
<i>Bos taurus</i>	British Park cattle.....	5
<i>Bubalus bubalis</i>	Water buffalo.....	2
<i>Capra hircus</i>	Domestic goat.....	1
<i>Capra sibirica</i>	Ibex.....	1
<i>Cephalophus maxwellii</i>	Maxwell's duiker.....	1
<i>Cephalophus niger</i>	Black duiker.....	1
<i>Cephalophus nigrifrons</i>	Black-fronted duiker.....	2
<i>Hemitragus jemlahicus</i>	Tahr.....	5
<i>Oreotragus oreotragus</i>	South African klipspringer.....	1
<i>Oryx beisa annectens</i>	Ibean beisa oryx.....	1

MAMMALS—continued

ARTIODACTYLA—continued

<i>Scientific name</i>	<i>Common name</i>	<i>Number</i>
Bovidae—Continued		
<i>Oryx leucoryx</i>	Arabian oryx.....	3
<i>Ovis aries</i>	Woolless or Barbadoes sheep.....	1
<i>Ovis europaea</i>	Mouflon.....	4
<i>Poephagus grunniens</i>	Yak.....	6
<i>Pseudois nayaur</i>	Bharal or blue sheep.....	1
<i>Sus scrofa</i>	Wild boar.....	2
<i>Syncerus caffer</i>	African buffalo.....	2
<i>Taurotragus oryx</i>	Eland.....	3
Cervidae:		
<i>Axis axis</i>	Axis deer.....	5
<i>Cervus canadensis</i>	American elk.....	5
<i>Cervus elaphus</i>	Red deer.....	4
<i>Cervus nippon</i>	Japanese deer.....	3
<i>Cervus nippon manchuricus</i>	Dybowsky deer.....	2
<i>Dama dama</i>	{ Fallow deer.....	9
	{ White fallow deer.....	11
<i>Odocoileus virginianus</i>	Virginia deer.....	5
Giraffidae:		
<i>Giraffa camelopardalis</i>	Nubian giraffe.....	4
<i>Giraffa reticulata</i>	Reticulated giraffe.....	1
Camelidae:		
<i>Camelus bactrianus</i>	Bactrian camel.....	3
<i>Camelus dromedarius</i>	Single-humped camel.....	1
<i>Lama glama</i>	Llama.....	2
<i>Lama glama guanico</i>	Guanaco.....	1
<i>Lama pacos</i>	Alpaca.....	2
<i>Vicugna vicugna</i>	Vicuña.....	1
Tayassuidae:		
<i>Pecari angulatus</i>	Collared peccary.....	1
Suidae:		
<i>Babirussa babyrussa</i>	Babirussa.....	2
<i>Phacochoerus aethiopicus aeliani</i>	East African wart hog.....	3
Hippopotamidae:		
<i>Choeropsis liberiensis</i>	Pigmy hippopotamus.....	5
<i>Hippopotamus amphibius</i>	Hippopotamus.....	2
PERISSODACTYLA		
Equidae:		
<i>Equus burchellii antiquorum</i>	Chapman's zebra.....	2
<i>Equus grevyi</i>	Grevy's zebra.....	1
<i>Equus grevyi</i> × <i>caballus</i>	Zebra-horse hybrid.....	1
<i>Equus kiang</i>	Asiatic wild ass or kiang.....	1
<i>Equus onager</i>	Onager.....	1
<i>Equus przewalskii</i>	Mongolian wild horse.....	3
<i>Equus zebra</i>	Mountain zebra.....	1
Tapiridae:		
<i>Acrocodia indica</i>	Asiatic tapir.....	2
<i>Tapirus terrestris</i>	South American tapir.....	1

MAMMALS—continued

PERISSODACTYLA—continued

Scientific name	Common name	Number
Rhinocerotidae:		
<i>Rhinoceros unicornis</i> -----	Great Indian one-horned rhinoceros -----	1

PROBOSCIDAE

Elephantidae:

<i>Elephas maximus sumatranus</i> -----	Sumatran elephant-----	1
<i>Loxodonta africana oxyotis</i> -----	African elephant-----	1

EDENTATA

Choloepodidae:

<i>Choloepus didactylus</i> -----	Two-toed sloth-----	3
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Dasypodidae:

<i>Chaetophractus villosus</i> -----	Hairy armadillo-----	1
<i>Euphractus sexcinctus</i> -----	Six-banded armadillo-----	2

Myrmecophagidae:

<i>Myrmecophaga tridactyla</i> -----	Giant anteater-----	1
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BIRDS

STRUTHIONIFORMES

Struthionidae:

<i>Struthio camelus</i> -----	Ostrich -----	2
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RHEIFORMES

Rheidae:

<i>Rhea americana</i> -----	Common rhea -----	3
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CASUARIIFORMES

Casuariidae:

<i>Casuarus bennetti papuanus</i> -----	Papuan Cassowary -----	1
<i>Casuarus casuarus aruensis</i> -----	Aru cassowary -----	1
<i>Casuarus uniappendiculatus occipitalis</i> -----	Island cassowary-----	1
<i>Casuarus uniappendiculatus uniappendic- latus</i> -----	One-wattled cassowary-----	1

Dromiceidae:

<i>Dromiceius novaehollandiae</i> -----	Common emu-----	2
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SPHENISCIFORMES

Spheniscidae:

<i>Aptenodytes forsteri</i> -----	Emperor penguin-----	3
<i>Spheniscus demersus</i> -----	Jackass penguin-----	4
<i>Spheniscus humboldti</i> -----	Humboldt penguin-----	2

TINAMIFORMES

Tinamidae:

<i>Eudromia elegans</i> -----	Crested tinamou or martineta-----	1
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BIRDS—continued

PELECANIFORMES

Scientific name	Common name	Number
Pelecanidae:		
<i>Pelecanus conspicillatus</i>	Australian pelican.....	2
<i>Pelecanus erythrorhynchus</i>	White pelican.....	5
<i>Pelecanus occidentalis</i>	Brown pelican.....	5
<i>Pelecanus onocrotalus</i>	European pelican.....	2
Phalacrocoracidae:		
<i>Phalacrocorax auritus albociliatus</i>	Farallon cormorant.....	1
Fregatidae:		
<i>Fregata ariel</i>	Lesser frigate bird.....	1

CICONIIFORMES

Ardeidae:		
<i>Ardea herodias</i>	Great blue heron.....	2
<i>Ardea occidentalis</i>	Great white heron.....	1
<i>Egretta thula</i>	Snowy egret.....	5
<i>Florida caerulea</i>	Little blue heron.....	1
<i>Hydranassa tricolor ruficollis</i>	Louisiana heron.....	2
<i>Notophox novaehollandiae</i>	White-faced heron.....	1
<i>Nyctanassa violacea cayennensis</i>	South American yellow-crowned night heron.....	1
<i>Nycticorax nycticorax naevius</i>	Black-crowned night heron.....	20
Cochleariidae:		
<i>Cochlearius cochlearius</i>	Boatbill heron.....	1
Ciconiidae:		
<i>Dissoura episcopus</i>	Woolly-necked stork.....	1
<i>Ibis cinereus</i>	Malay stork.....	2
<i>Leptoptilus crumeniferus</i>	Marabou.....	1
<i>Leptoptilus dubius</i>	Indian adjutant.....	1
<i>Leptoptilus javanicus</i>	Lesser adjutant.....	2
<i>Mycteria americana</i>	Wood ibis.....	1
Threskiornithidae:		
<i>Ajaia ajaja</i>	Roseate spoonbill.....	4
<i>Guara alba</i>	White ibis.....	8
<i>Guara alba</i> × <i>G. rubra</i>	Hybrid white and scarlet ibis.....	1
<i>Guara rubra</i>	Scarlet ibis.....	1
<i>Threskiornis aethiopica</i>	Sacred ibis.....	1
<i>Threskiornis melanocephala</i>	Black-headed ibis.....	4
<i>Threskiornis spinicollis</i>	Straw-necked ibis.....	2
Phoenicopteridae:		
<i>Phoenicopus chilensis</i>	Chilean flamingo.....	1
<i>Phoenicopus ruber</i>	Cuban flamingo.....	3

ANSERIFORMES

Anhimidae:		
<i>Chauna chavaria</i>	White-cheeked screamer.....	1
<i>Chauna critata</i>	Crested screamer.....	7

BIRDS—continued

ANSERIFORMES—continued

Scientific name	Common name	Number
Anatidae:		
<i>Aix sponsa</i>	Wood duck.....	6
<i>Anas brasiliensis</i>	Brazilian teal.....	2
<i>Anas domestica</i>	Pekin duck.....	25
<i>Anas platyrhynchos</i>	Mallard duck.....	61
<i>Anas rubripes</i>	Black duck.....	7
<i>Anser albifrons</i>	American white-fronted goose.....	1
<i>Anser cinereus domestica</i>	Toulouse goose.....	2
<i>Anseranus semipalmata</i>	Australian pied goose.....	2
<i>Branta canadensis</i>	Canada goose.....	37
<i>Branta canadensis occidentalis</i>	White-cheeked goose.....	26
<i>Branta canadensis</i> × <i>Chen caerulescens</i>	Hybrid Canada goose × blue goose.....	2
<i>Branta hutchinsii</i>	Hutchin's goose.....	4
<i>Branta hutchinsii minima</i>	Cackling goose.....	8
<i>Cairina moschata</i>	Muscovy duck.....	16
<i>Cercopsis novaehollandiae</i>	Cape Barren goose.....	1
<i>Chen atlantica</i>	Snow goose.....	2
<i>Chen caerulescens</i>	Blue goose.....	2
<i>Chenopsis atrata</i>	Black swan.....	4
<i>Chloephaga leucoptera</i>	Magellan goose.....	1
<i>Cygnopsis cygnoides</i>	Domestic goose.....	2
<i>Cygnus columbianus</i>	Whistling swan.....	3
<i>Cygnus melancoriphus</i>	Black-necked swan.....	1
<i>Cygnus olor</i>	Mute swan.....	3
<i>Dafila acuta</i>	Pintail.....	8
<i>Dafila spinicauda</i>	Chilean pintail.....	1
<i>Dendrocygna arborea</i>	Black-billed tree duck.....	3
<i>Dendrocygna autumnalis</i>	Black-bellied tree duck.....	2
<i>Dendrocygna viduata</i>	White-faced tree duck.....	4
<i>Dendrocygna galariculata</i>	Mandarin duck.....	4
<i>Mareca americana</i>	Baldpate.....	1
<i>Marila affinis</i>	Lesser scaup.....	1
<i>Marila collaris</i>	Ring-necked duck.....	1
<i>Nettion carolinense</i>	Green-winged teal.....	1
<i>Nettion formosum</i>	Baikal teal.....	5
<i>Nyroca</i> sp.....	Hybrid duck.....	1
<i>Nyroca americana</i>	Red-head duck.....	2
<i>Nyroca valisineria</i>	Canvasback duck.....	1
<i>Philacte canagica</i>	Emperor goose.....	3
<i>Querquedula discors</i>	Blue-winged teal.....	6

FALCONIFORMES

Cathartidae:

<i>Cathartes aura</i>	Turkey vulture.....	2
<i>Coragyps atratus</i>	Black vulture.....	2
<i>Gymnogyps californianus</i>	California condor.....	1
<i>Vultur gryphus</i>	Andean condor.....	1

BIRDS—continued

FALCONIFORMES—continued

Scientific name	Common name	Number
Accipitridae:		
<i>Accipiter striatus velox</i> -----	Sharp-shinned hawk-----	2
<i>Buteo borealis</i> -----	Red-tailed hawk-----	7
<i>Buteo lineatus elegans</i> -----	Southern red-shouldered hawk-----	1
<i>Buteo lineatus lineatus</i> -----	Red-shouldered hawk-----	1
<i>Buteo melanoleucus</i> -----	South American buzzard eagle-----	2
<i>Buteo platypterus</i> -----	Broad-winged hawk-----	1
<i>Buteo poecliochrous</i> -----	Red-backed buzzard-----	3
<i>Gypohierax angolensis</i> -----	Fish-eating vulture-----	1
<i>Gyps rueppelli</i> -----	Ruppell's vulture-----	1
<i>Haliaeetus leucocephalus</i> -----	Bald eagle-----	7
<i>Haliastur indus</i> -----	Brahminy kite-----	5
<i>Harpia harpya</i> -----	Harpy eagle-----	2
<i>Hypomorphnus urubitinga</i> -----	Brazilian eagle-----	1
<i>Milvago chimango</i> -----	Chimango-----	3
<i>Milvus migrans parasitus</i> -----	African yellow-billed kite-----	2
<i>Pandion haliaetus carolinensis</i> -----	Osprey or fish hawk-----	1
<i>Parabuteo unicinctus</i> -----	One-banded hawk-----	1
<i>Torgos tracheliotus</i> -----	African eared vulture-----	1
Falconidae:		
<i>Cerchneis sparverius</i> -----	Sparrow hawk-----	8
<i>Cerchneis sparverius interaediis</i> -----	South American sparrow hawk-----	1
<i>Daptrius americanus</i> -----	Red-throated caracara-----	3
<i>Falco deiroleucus</i> -----	Bat falcon-----	1
<i>Falco peregrinus anatum</i> -----	Duck hawk-----	2
<i>Polyborus plancus</i> -----	South American caracara-----	1

GALLIFORMES

Cracidae:

<i>Craz fasciolata</i> -----	Crested curassow-----	1
<i>Craz rubra</i> -----	Panama curassow-----	1
<i>Craz sclateri</i> -----	Sclater's curassow-----	1
<i>Mitu mitu</i> -----	Razor-billed curassow-----	1

Phasianidae:

<i>Argusianus argus</i> -----	Argus pheasant-----	2
<i>Catreus callichi</i> -----	Cheer pheasant-----	2
<i>Chrysolophus amherstiae</i> -----	Lady Amherst's pheasant-----	1
<i>Chrysolophus pictus</i> -----	Golden pheasant-----	5
<i>Colinus cristatus</i> -----	Crested quail-----	2
<i>Crossoptilon auritum</i> -----	Blue-eared pheasant-----	1
<i>Gallus sp</i> -----	Bantam chicken-----	1
<i>Gallus sp</i> -----	Oriental silky bantam fowl-----	2
<i>Gallus sp</i> -----	Fighting fowl-----	1
<i>Gallus sp</i> -----	Long-tailed fowl-----	1
<i>Gallus gallus</i> -----	Red jungle fowl-----	2
<i>Gallus gallus</i> -----	Hybrid red jungle fowl × Bantam fowl-----	3
<i>Gallus lafayetti</i> -----	Ceylonese jungle fowl-----	1

BIRDS—continued

GALLIFORMES—continued

Scientific name	Common name	Number
Phasianidae—Continued		
<i>Gallus lafayetii</i> × <i>G. gallus</i>	Chicken hybrid.....	1
<i>Gallus sonnerati</i>	Gray jungle fowl.....	1
<i>Gennaeus albocristatus</i>	White-crested kaleege.....	2
<i>Gennaeus nycthemerus</i>	Silver pheasant.....	3
<i>Hierophasis swinhoii</i>	Swinhoe's pheasant.....	2
<i>Lophophorus impeyanus</i>	Himalayan impeyan pheasant.....	1
<i>Pavo cristatus</i>	Peafowl.....	6
<i>Phasianus torquatus</i>	Ring-necked pheasant.....	4
	White ring-necked pheasant.....	1
<i>Polyplectron napoleonis</i>	Palawan peacock pheasant.....	1
<i>Symaticus reevesi</i>	Reeve's pheasant.....	1
Numididae:		
<i>Acryllium vulturinum</i>	Vulturine guinea fowl.....	1
<i>Numida</i> sp.....	Guinea fowl.....	4

GRUIFORMES

Rhinochetidae:		
<i>Rhinoceros jubatus</i>	Kagu.....	1
Gruidae:		
<i>Anthropoides virgo</i>	Demoiselle crane.....	2
<i>Balearica pavonina</i>	West African crowned crane.....	2
<i>Balearica regulorum gibbericeps</i>	East African crowned crane.....	1
<i>Grus leucauchen</i>	White-naped crane.....	1
<i>Grus leucogeranus</i>	Siberian crane.....	2
Rallidae:		
<i>Amaurornis phoenicurus</i>	White-breasted rail.....	2
<i>Aramides cayennensis</i>	Wood rail.....	2
<i>Fulica americana</i>	American coot.....	8
<i>Gallinula chloropus cachinnans</i>	Florida gallinule.....	3
<i>Gallinula chloropus orientalis</i>	Sumatran gallinule.....	1
<i>Limnocorax flavirostris</i>	African black rail.....	3
<i>Porphyrio poliocephalus</i>	Gray-headed porphyrio.....	1
Cariamidae:		
<i>Cariama cristata</i>	Cariama or seriama.....	2

CHARADRIIFORMES

Haematopodidae:		
<i>Haematopus ostralegus</i>	European oyster catcher.....	1
Charadriidae:		
<i>Belonopterus chilensis</i>	Chilean lapwing.....	1
Laridae:		
<i>Larus argentatus</i>	Herring gull.....	1
<i>Larus delawarensis</i>	Ring-billed gull.....	1
<i>Larus dominicanus</i>	Kelp gull.....	2
<i>Larus glaucescens</i>	Glaucous-winged gull.....	1
<i>Larus novae-hollandiae</i>	Silver gull.....	10
Glariolidae:		
<i>Glareola pratincola</i>	Collared pratincole.....	1

BIRDS—continued

COLUMBIFORMES

<i>Scientific name</i>	<i>Common name</i>	<i>Number</i>
Columbidae:		
<i>Columba guinea</i>	Triangular-spotted pigeon.....	1
<i>Columba livia</i>	Domestic pigeon.....	3
<i>Columbigallina passerina</i>	Ground dove.....	2
<i>Ducula aenea</i>	Green imperial pigeon.....	1
<i>Ducula paulina</i>	Imperial pigeon.....	1
<i>Gallicolumba luzonica</i>	Bleeding-heart dove.....	2
<i>Goura cristata</i>	Slater's crowned pigeon.....	1
<i>Goura victoria</i>	Victoria crowned pigeon.....	1
<i>Leptotila cassini</i>	Cassin's dove.....	1
<i>Leptotila rufaxilla</i>	Scaled pigeon.....	1
<i>Muscadivores paulina</i>	Celebian imperial pigeon.....	1
<i>Streptopelia chinensis</i>	Asiatic collared dove.....	2
<i>Streptopelia chinensis ceylonensis</i>	Lace-necked or ash dove.....	3
<i>Streptopelia tranquebarica</i>	Blue-headed ring dove.....	2
<i>Turtur risorius</i>	Ring-necked dove.....	33
<i>Zenaida auriculata</i>	South America mourning dove.....	5
<i>Zenaidura macroura</i>	Mourning dove.....	2

PSITTACIFORMES

Psittacidae:		
<i>Agapornis lilianae</i>	Peach-faced love bird.....	2
<i>Agapornis pullaria</i>	Red-faced love bird.....	2
<i>Amazona aestiva</i>	Blue-fronted parrot.....	1
<i>Amazona auropalliata</i>	Yellow-naped parrot.....	2
<i>Amazona ochrocephala</i>	Yellow-headed parrot.....	2
<i>Amazona oratrix</i>	Double yellow-headed parrot.....	3
<i>Anodorhynchus hyacinthinus</i>	Hyacinthine macaw.....	1
<i>Ara ararauna</i>	Yellow and blue macaw.....	1
<i>Ara macao</i>	Red, blue, and yellow macaw.....	1
<i>Aratinga euops</i>	Cuban conure.....	1
<i>Aratinga pertinax</i>	Gray-headed conure.....	1
<i>Calyptorhynchus magnificus</i>	Banksian cockatoo.....	1
<i>Coracopsis nigra</i>	Lesser vasa parrot.....	1
<i>Cyanopsittacus spizi</i>	Spix's macaw.....	1
<i>Ducorpsis sanguineus</i>	Bare-eyed cockatoo.....	2
<i>Eclectus pectoralis</i>	Eclectus parrot.....	1
<i>Eolophus roseicapillus</i>	Roseate cockatoo.....	2
<i>Kakatoe alba</i>	White cockatoo.....	2
<i>Kakatoe ducrops</i>	Solomon Islands cockatoo.....	2
<i>Kakatoe galerita</i>	Large sulphur-crested cockatoo.....	2
<i>Kakatoe leadbeateri</i>	Leadbeater's cockatoo.....	1
<i>Kakatoe moluccensis</i>	Great red-crested cockatoo.....	1
<i>Kakatoe sulphurea</i>	Lesser sulphur-crested cockatoo.....	1
<i>Lorius domicella</i>	Rajah lory.....	2
<i>Lorius garrulus</i>	Red lory.....	1

BIRDS—continued

PSITTACIFORMES—continued

Scientific name	Common name	Number
Psittacidae—Continued		
<i>Lorius loratus</i>	Red-sided lory.....	1
<i>Melopsittacus undulatus</i>	Grass paroquet.....	5
<i>Myopsitta monachus</i>	Quaker paroquet.....	1
<i>Nandayus nanday</i>	Nanday paroquet.....	1
<i>Nestor notabilis</i>	Kea.....	1
<i>Pionites xanthomera</i>	Amazonian calque.....	2
<i>Psittacula eupatria</i>	Red-shouldered paroquet.....	3
<i>Psittacula krameri</i>	Kramer's paroquet.....	2
<i>Psittacula longicauda</i>	Long-tailed paroquet.....	1

CUCULIFORMES

Cuculidae:

<i>Eudynamis scolopaceus</i>	Koel.....	1
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STRIGIFORMES

Tytonidae:

<i>Tyto alba pratincola</i>	Barn owl.....	5
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Strigidae:

<i>Bubo virginianus</i>	Great horned owl.....	9
<i>Ketupa ketupa</i>	Malay fish owl.....	1
<i>Nyctea nyctea</i>	Snowy owl.....	1
<i>Otus asio</i>	Screech owl.....	1
<i>Strix varia varia</i>	Barred owl.....	6

TROGONIFORMES

Trogonidae:

<i>Pharomachrus mocino</i>	Quetzal.....	3
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CORACIIFORMES

Alcedinidae:

<i>Dacelo gigas</i>	Kookaburra.....	2
<i>Halcyon sanctus</i>	Sacred kingfisher.....	1

Momotidae:

<i>Momotus lessoni</i>	Motmot.....	1
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PICIFORMES

Ramphastidae:

<i>Aulacorhynchus sulcatus sulcatus</i>	Groove-billed toucanet.....	1
<i>Pteroglossus aracari</i>	Black-necked aracari.....	1
<i>Pteroglossus torquatus</i>	Aracari toucan.....	1
<i>Ramphastos carinatus</i>	Sulphur-breasted toucan.....	6
<i>Ramphastos piscivorus</i>	Toco toucan.....	1

Capitonidae:

<i>Cyanops asiatica</i>	Red-capped barbet.....	1
<i>Cyanops zeylanica</i>	Streaked barbet.....	1
<i>Megalaima zanonica</i>	Streaked barbet.....	1

BIRDS—continued

PASSERIFORMES

<i>Scientific name</i>	<i>Common name</i>	<i>Number</i>
Cotingidae:		
<i>Rupicola peruviana sanguinolenta</i> -----	Scarlet cock-of-the-rock-----	1
<i>Rupicola rupicola</i> -----	Cock-of-the-rock-----	3
Corvidae:		
<i>Callocitta formosa</i> -----	Mexican jay-----	1
<i>Cissa chinensis</i> -----	Chinese cissa-----	2
<i>Cissilopha yucatanica</i> -----	Yucatan bluejay-----	4
<i>Corvus albus</i> -----	White-breasted crow-----	2
<i>Corvus brachyrhynchus</i> -----	American crow-----	8
<i>Corvus corax principalis</i> -----	Northern raven-----	2
<i>Corvus cornix</i> -----	Hooded crow-----	1
<i>Corvus cryptoleucus</i> -----	White-necked raven-----	1
<i>Corvus insolens</i> -----	Indian crow-----	3
<i>Cyanocitta cristata</i> -----	Blue jay-----	1
<i>Cyanocorax chrysops</i> -----	Urraca jay-----	1
<i>Cyanocorax mystacalis</i> -----	Moustached jay-----	1
<i>Cyanopica cyana</i> -----	Azure-winged pie-----	2
<i>Gymnorhina hypoleuca</i> -----	White-backed piping crow-----	1
<i>Pica pica hudsonica</i> -----	American magpie-----	5
<i>Urocissa caerulea</i> -----	Formosan red-billed pie-----	2
<i>Urocissa occipitalis</i> -----	Red-billed blue magpie-----	1
Paradisidae:		
<i>Ailuroedus crassirostris</i> -----	Australian catbird-----	1
<i>Ptilonorhynchus violaceus</i> -----	Satin bowerbird-----	1
Pycnonotidae:		
<i>Pycnonotus analis</i> -----	Yellow-vented bulbul-----	1
Timaliidae:		
<i>Leiothrix luteus</i> -----	Pekin robin-----	1
<i>Pomatorhinus erythrogenys</i> -----	Scimitar babbler-----	1
Mimidae:		
<i>Melanotis caerulescens</i> -----	Blue catbird-----	1
<i>Mimus polyglottos</i> -----	Mockingbird-----	1
Turdidae:		
<i>Garrulax sp</i> -----	Asiatic thrush-----	3
<i>Garrulax belangeri</i> -----	Burmese thrush-----	3
<i>Garrulax pectoralis picticollis</i> -----	Chinese collared laughing thrush-----	1
<i>Hylocichla mustelina</i> -----	Wood thrush-----	1
<i>Platycichla flavipes</i> -----	Yellow-footed thrush-----	1
<i>Turdus grayi</i> -----	Bonaparte's thrush-----	1
<i>Turdus migratorius</i> -----	Eastern robin-----	1
<i>Turdus rufiventris</i> -----	Argentine robin-----	1
Sturnidae:		
<i>Creatophora cinerea</i> -----	Wattled starling-----	1
<i>Galeopsar salvadorii</i> -----	Crested starling-----	1
<i>Gracula religiosa</i> -----	Hill mynah-----	1
<i>Graculipica melanoptera</i> -----	White starling-----	1
<i>Pastor roseus</i> -----	Rosy pastor-----	2

BIRDS—continued

PASSERIFORMES—continued

<i>Scientific name</i>	<i>Common name</i>	<i>Number</i>
Sturnidae—Continued		
<i>Sturnia malabarica</i> -----	Pied mynah-----	2
<i>Sturnus vulgaris</i> -----	Starling-----	1
<i>Temenuchus pagodarum</i> -----	Black-headed mynah-----	2
Floceidae:		
<i>Diatropura procne</i> -----	Giant whydah-----	2
<i>Erythrura psittacea</i> -----	New Caledonian parrot finch-----	1
<i>Lonchura leucogastroides</i> -----	Bengalee-----	2
<i>Munia maja</i> -----	White-headed munia-----	2
<i>Munia malacca</i> -----	Black-throated munia-----	1
<i>Munia oryzivora</i> -----	Java sparrow-----	5
<i>Munia punctulatus</i> -----	Rice bird or nutmeg finch-----	1
<i>Ploceus baya</i> -----	Baya weaver-----	3
<i>Ploceus intermedius</i> -----	Black-cheeked weaver-----	3
<i>Poephila acuticauda</i> -----	Long-tailed finch-----	1
<i>Poephila gouldiae</i> -----	Gouldian finch-----	2
<i>Quelea sanguirostris intermedia</i> -----	Southern masked weaver finch-----	2
<i>Steganura paradisaea</i> -----	Paradise whydah-----	1
<i>Taeniopygia castanotis</i> -----	Zebra finch-----	12
Icteridae:		
<i>Agelaius assimilis</i> -----	Cuban red-winged blackbird-----	1
<i>Cassidix melanicterus</i> -----	Mexican cacique-----	1
<i>Gymnomystax mexicanus</i> -----	Giant oriole-----	1
<i>Icterus bullocki</i> -----	Bullock's troupial-----	2
<i>Icterus icterus</i> -----	Troupial-----	1
<i>Molothrus bonariensis</i> -----	Shiny cowbird-----	1
<i>Notiospar curaeus</i> -----	Chilean blackbird-----	2
<i>Trupialis defilippi</i> -----	Military starling-----	4
<i>Xanthocephalus xanthocephalus</i> -----	Yellow-headed blackbird-----	6
Thraupidae:		
<i>Calospiza cyanicollis</i> -----	Blue-necked tanager-----	2
<i>Chlorophonia occipitalis</i> -----	Central American chloro- phonia-----	2
<i>Piranga bidentata</i> -----	Orange tanager-----	1
<i>Rhamphocelus carbo</i> -----	Silver-beaked tanager-----	2
<i>Ramphocelus dimidiatus</i> -----	Crimson tanager-----	1
<i>Ramphocelus flammigerus</i> -----	Yellow tanager-----	4
<i>Ramphocelus icteronotus</i> -----	Yellow-rumped tanager-----	2
<i>Tanagra darwini</i> -----	Darwin's tanager-----	3
<i>Tanagra musica</i> -----	Blue-hooded euphonia-----	2
<i>Thraupis cana</i> -----	Blue tanager-----	2
Fringillidae:		
<i>Amandava amandava</i> -----	Strawberry finch-----	9
<i>Carpodacus mexicanus</i> -----	Mexican house finch-----	4
<i>Coryphospingus cucullatus</i> -----	Red-crested finch-----	1
<i>Cyanocompsa argentina</i> -----	Argentine blue grosbeak-----	2
<i>Diuca diuca</i> -----	Diuca finch-----	1
<i>Junco hyemalis</i> -----	Slate-colored junco-----	1

BIRDS—continued

PASSERIFORMES—continued

Scientific name	Common name	Number
Fringillidae—Continued		
<i>Lophospingus pusillus</i> -----	Black-crested finch-----	3
<i>Melopyrrha nigra</i> -----	Cuban bullfinch-----	1
<i>Melospiza melodia</i> -----	Song sparrow-----	2
<i>Paroaria cucullata</i> -----	Brazilian cardinal-----	2
<i>Paroaria gularis nigro-genis</i> -----	Black-eared cardinal-----	3
<i>Passerella iliaca</i> -----	Fox sparrow-----	1
<i>Passerina amoena</i> -----	Lazuli bunting-----	4
<i>Passerina cyanea</i> -----	Indigo bunting-----	2
<i>Passerina leclancheri</i> -----	Leclancher's bunting-----	6
<i>Passerina versicolor</i> -----	Blue bunting-----	2
<i>Phrygilus alaudinos</i> -----	Chilean lark finch-----	1
<i>Phrygilus fruticeti</i> -----	Mourning finch-----	2
<i>Phrygilus gayi</i> -----	Gay's gray-headed finch-----	1
<i>Richmondina cardinalis</i> -----	Cardinal-----	4
<i>Serinus canarius</i> -----	Canary-----	2
<i>Sicalis flaveola</i> -----	Mysto finch-----	1
<i>Sicalis luteola</i> -----	Saffron finch-----	2
<i>Sicalis minor</i> -----	Lesser yellow finch-----	4
<i>Spinus uropygialis</i> -----	Chilean siskin-----	3
<i>Sporophila aurita</i> -----	Hick's seed-eater-----	2
<i>Sporophila gutturalis</i> -----	Yellow-billed seed-eater-----	2
<i>Tiariis olivacea</i> -----	Mexican grassquit-----	2
<i>Volatinia jacarini</i> -----	Blue-black grassquit-----	1
<i>Zonotrichia albicollis</i> -----	White-throated sparrow-----	5
<i>Zonotrichia capensis</i> -----	Chingolo-----	4

REPTILES

LOBICATA

Crocodylidae:

<i>Alligator mississippiensis</i> -----	Alligator-----	21
<i>Alligator sinensis</i> -----	Chinese alligator-----	3
<i>Caiman latirostris</i> -----	Broad-snouted caiman-----	1
<i>Caiman sclerops</i> -----	Spectacled caiman-----	3
<i>Crocodylus acutus</i> -----	American crocodile-----	4
<i>Crocodylus cataphractus</i> -----	Narrow-nosed crocodile-----	1
<i>Crocodylus niloticus</i> -----	African crocodile-----	2
<i>Crocodylus palustris</i> -----	"Toad" crocodile-----	2
<i>Crocodylus porosus</i> -----	Salt-water crocodile-----	1
<i>Crocodylus rhombifer</i> -----	Cuban crocodile-----	1
<i>Osteolaemus tetraspis</i> -----	Broad-nosed crocodile-----	3

SAURIA

Gekkonidae:

<i>Gekko gekko</i> -----	Gecko-----	2
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Iguanidae:

<i>Anolis carolinensis</i> -----	False "chameleon"-----	15
<i>Crotaphytus collaris</i> -----	Collared lizard-----	6

REPTILES—continued

SAURIA—continued

Scientific name	Common name	Number
Iguanidae—Continued		
<i>Iguana iguana</i>	Common iguana.....	1
<i>Phrynosoma cornutum</i>	Horned lizard.....	5
<i>Sceloporus undulatus</i>	Pine or fence lizard.....	15
Anguidae:		
<i>Ophisaurus ventralis</i>	Glass snake or legless lizard.....	3
Agamidae:		
<i>Uromastix acanthinurus</i>	North African spiny-tailed lizard.....	1
Helodermatidae:		
<i>Heloderma horridum</i>	Mexican beaded lizard.....	2
<i>Heloderma suspectum</i>	Gila monster.....	5
Telidae:		
<i>Cnemidophorus sexlineatus</i>	Six-lined race runner.....	1
Scincidae:		
<i>Eumeces fasciatus</i>	Blue-tailed skink.....	2
<i>Tiliqua scincoides</i>	Blue-tongued lizard.....	2
Varanidae:		
<i>Varanus komodoensis</i>	Komodo dragon.....	1
<i>Varanus monitor</i>	Indian monitor.....	1
<i>Varanus niloticus</i>	Nile monitor.....	2
<i>Varanus salvator</i>	Sumatran monitor.....	3
Zonuridae:		
<i>Zonurus giganteus</i>	African spiny lizard.....	6

SERPENTES

Boidae:		
<i>Calabaria reinhardtii</i>	Burrowing python.....	1
<i>Constrictor constrictor</i>	Boa constrictor.....	1
<i>Constrictor imperator</i>	Central American boa.....	7
<i>Epicrates cenchris</i>	Rainbow boa.....	30
<i>Epicrates crassus</i>	Salamanta.....	1
<i>Epicrates striatus</i>	Haitian boa.....	1
<i>Eunectes murinus</i>	Anaconda.....	1
<i>Python molurus</i>	Indian rock python.....	1
<i>Python regius</i>	Ball python.....	1
<i>Tropidophis melanurus</i>	Cuban boa.....	1
Colubridae:		
<i>Coluber constrictor</i>	Black snake.....	2
<i>Coluber flagellum</i>	Coachwhip.....	1
<i>Diadophis punctatus</i>	Ring-necked snake.....	1
<i>Dinodon semicarinatum</i>	Akamatah.....	2
<i>Drymarchon corais couperi</i>	Indigo snake.....	3
<i>Elaphe guttata</i>	Corn snake.....	4
<i>Elaphe obsoleta</i>	Pilot snake.....	3
<i>Heterodon contortrix</i>	Hog-nosed snake.....	5
<i>Lampropeltis getulus</i>	Chain king snake.....	1
<i>Natrix</i> sp.....	Water snake.....	15

REPTILES—continued

SERPENTES—continued

<i>Scientific name</i>	<i>Common name</i>	<i>Number</i>
Colubridae—Continued		
<i>Natrix</i> sp.-----	Indian water snake-----	1
<i>Natrix piscator</i> -----	Water snake-----	1
<i>Oxybelis fulgidus</i> -----	Green tree snake-----	1
<i>Pituophis melanoleucus</i> -----	Bull snake-----	2
<i>Storeria dekayi</i> -----	De Kay's snake-----	5
<i>Thamnophis ordinoides</i> -----	Western garter snake-----	2
<i>Thamnophis sirtalis</i> -----	Garter snake-----	10
<i>Thrasops jacksoni</i> -----	Black tree snake-----	1
Elapidae:		
<i>Naja melanoleuca</i> -----	West African cobra-----	3
<i>Naja naja</i> -----	Indian cobra-----	5
Crotalidae:		
<i>Agkistrodon mokeson</i> -----	Copperhead snake-----	3
<i>Crotalus terrificus</i> -----	South American rattlesnake--	1
<i>Trimeresurus flavoviridis</i> -----	Habu-----	6
Viperidae:		
<i>Vipera russellii</i> -----	Russell's viper-----	1

TESTUDINATA

Chelydridae:		
<i>Batrachemys nasuta</i> -----	South American side-necked turtle-----	3
<i>Hydraspis</i> sp.-----	South American snake-necked turtle-----	3
<i>Hydromedusa tectifera</i> -----	South American long-necked turtle-----	16
<i>Platemys platycephala</i> -----	Flat-headed turtle-----	1
Platysternidae:		
<i>Platysternum megacephalum</i> -----	Large-headed Chinese turtle--	1
Pelomedusidae:		
<i>Pelomedusa galeata</i> -----	Common African water tor- toise-----	1
<i>Podocnemis expansa</i> -----	South American river tortoise--	1
Kinosternidae:		
<i>Kinosternon</i> sp.-----	Central American musk turtle--	1
<i>Kinosternon subrubrum</i> -----	Musk turtle-----	4
Chelydridae:		
<i>Chelydra serpentina</i> -----	Snapping turtle-----	8
<i>Macrochelys temminckii</i> -----	Alligator snapping turtle-----	1
Testudinidae:		
<i>Chrysemys marginata</i> -----	Western painted turtle-----	5
<i>Chrysemys picta</i> -----	Painted turtle-----	3
<i>Clemmys guttata</i> -----	Spotted turtle-----	6
<i>Clemmys insculpta</i> -----	Wood turtle-----	6
<i>Cyclemys amboinensis</i> -----	Kura kura box turtle-----	2
<i>Geoclemys subtrijuga</i> -----	Siamese field turtle-----	1
<i>Geoemyda manni</i> -----	Costa Rican terrapin-----	3

REPTILES—continued

TESTUDINATA—continued

<i>Scientific name</i>	<i>Common name</i>	<i>Number</i>
Testudinidae—Continued		
<i>Graytemys barbouri</i>	Barbour's turtle	6
<i>Kinixys erosa</i>	African hingeback turtle	3
<i>Malaclemys centrata</i>	Diamond-back turtle	24
<i>Pseudemys concinna</i>	Cooter	3
<i>Pseudemys elegans</i>	Cumberland terrapin	6
<i>Pseudemys ornata</i>	Central American water turtle	1
<i>Pseudemys rugosa</i>	Cuban terrapin	1
<i>Terrapene</i> sp.	Mexican box turtle	2
<i>Terrapene carolina</i>	Box turtle	50
<i>Terrapene major</i>	Florida box turtle	4
<i>Testudo denticulata</i>	South American land tortoise	2
<i>Testudo ephippium</i>	Duncan Island tortoise	1
<i>Testudo hoodensis</i>	Hood Island tortoise	3
<i>Testudo tornieri</i>	Soft-shelled land tortoise	1
<i>Testudo vicina</i>	Albemarle Island tortoise	6
Trionychidae:		
<i>Amyda ferox</i>	Soft-shelled turtle	6
<i>Amyda triunguis</i>	West African soft-shelled turtle	1

AMPHIBIA

CAUDATA

Salamandridae:		
<i>Triturus pyrrhogaster</i>	Red salamander	3
<i>Triturus torosus</i>	Giant newt	2
<i>Triturus vulgaris</i>	Common salamander	1
Amphiumidae:		
<i>Amphiuma means</i>	Blind eel or congo snake	1
Ambystomidae:		
<i>Ambystoma maculatum</i>	Spotted salamander	2
<i>Ambystoma trigrinum</i>	Axolotl	24

SALIENTIA

Dendrobatidae:		
<i>Atelopus stelzneri</i>	Black atelopus	30
<i>Atelopus varius cruciger</i>	Yellow atelopus	2
<i>Dendrobates auratus</i>	Arrow-poison frog	3
Bufonidae:		
<i>Bufo americanus</i>	Common toad	12
<i>Bufo empusus</i>	Sapo de concha	8
<i>Bufo marinus</i>	Marine toad	5
<i>Bufo peltoccephalus</i>	Cuban giant toad	3
Ceratophryidae:		
<i>Ceratophrys ornata</i>	Horned frog	2
Hylidae:		
<i>Acris gryllus</i>	Cricket frog	3
<i>Hyla crucifer</i>	Tree frog	6

AMPHIBIA—continued

SALIENTIA—continued

<i>Scientific name</i>	<i>Common name</i>	<i>Number</i>
Pipidae:		
<i>Pipa americana</i>	Surinam toad.....	12
<i>Xenopus laevis</i>	African clawed frog.....	32
Ranidae:		
<i>Rana catesbeiana</i>	Bullfrog.....	4
<i>Rana clamitans</i>	Green frog.....	3
<i>Rana occipitalis</i>	West African bullfrog.....	1
<i>Rana pipiens</i>	Leopard frog.....	15
<i>Rana sylvatica</i>	Wood frog.....	4

FISHES

<i>Aphyosemion australe</i>	Lyre-tailed fish.....	1
<i>Barbus everetti</i>	Clown barb.....	8
<i>Barbus sumatranus</i>		22
<i>Carassius auratus</i>	Goldfish.....	35
<i>Channa asiatica</i>	Snake head.....	1
<i>Corydoras</i> sp.....	Catfish.....	2
<i>Danio malabaricus</i>	Blue danio.....	7
<i>Danio rerio</i>	Zebra fish.....	8
<i>Gymnocorymbus ternetzi</i>	Black tetra.....	5
<i>Hemigrammus</i> sp.....	Tetra Buenos Aires.....	2
<i>Hyphessobrycon innesi</i>	Neon tetra fish.....	2
<i>Kryptopterus bicirrhis</i>	Glass catfish.....	2
<i>Lebistes reticulatus</i>	Guppy.....	100
<i>Lepidosiren paradoxa</i>	South American lungfish.....	2
<i>Limia vittata</i>	Cuban limia.....	10
<i>Macropodus</i> sp.....	Paradise fish.....	14
<i>Mesonauta insignis</i>		6
<i>Mollienisia sphenops</i>	Victory molly.....	20
<i>Platypoecilus</i>	Red moon.....	20
<i>Platypoecilus maculatus</i>	Goldplaties.....	12
<i>Plecostomus</i> sp.....	Armored catfish.....	1
<i>Pristella riddlei</i>		1
<i>Protopterus annectens</i>	African lungfish.....	2
<i>Pterophyllum scalare</i>	Angel fish.....	1
<i>Serrasalmus ternetzi</i>	Piranha or cannibal fish.....	1
<i>Trichogaster leeri</i>	Blue gourami.....	1
<i>Xiphophorus helleri</i>	Swordtail.....	1
	Tuxedo swordtail.....	8

ARACHNIDS

<i>Latrodectus mactans</i>	Black widow spider.....	1
<i>Eurypelma</i> sp.....	Tarantula.....	2
<i>Centruroides gracilis</i>	Mexican brown scorpion.....	1

INSECTS

<i>Blabera</i> sp.....	Giant cockroach.....	100
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MOLLUSKS

<i>Scientific name</i>	<i>Common name</i>	<i>Number</i>
<i>Achatina achatina</i>	Giant land snail.....	2

SUMMARY

Animals on hand July 1, 1945.....	2, 623
Accessions during the year.....	1, 108
<hr/>	
Total number of animals in collection during the year.....	3, 731
Removals for various reasons such as death, exchanges, return of animals on deposit, etc.....	1, 178
<hr/>	
In collection on June 30, 1946.....	2, 553

STATUS OF COLLECTION

Class	Species	Individuals	Class	Species	Individuals
Mammals	211	618	Insects	1	100
Birds	337	934	Mollusks	1	2
Reptiles	98	423	Arachnids	3	4
Amphibians	23	177			
Fish	27	295	Total	701	2, 553

Respectfully submitted.

W. M. MANN, *Director.*

Dr. A. WETMORE,

Secretary, Smithsonian Institution.

APPENDIX 8

REPORT ON THE ASTROPHYSICAL OBSERVATORY

SIR: I have the honor to submit the following report on the operations of the Astrophysical Observatory for the fiscal year ended June 30, 1946:

The Astrophysical Observatory comprises two divisions: (1) The Division of Astrophysical Research which is devoted to a study of solar radiation, and (2) the Division of Radiation and Organisms which investigates the effects of radiation upon organisms. The Observatory is supported largely by Congressional appropriation, amounting in this fiscal year to \$51,039, and in part by private funds. The equipment and housing of both divisions have remained nearly unchanged during the year.

(1) DIVISION OF ASTROPHYSICAL RESEARCH

Work at Washington.—In addition to the usual routine of correcting, recomputing, and verifying the solar observations as received from the three field stations (Montezuma, Chile; Table Mountain, Calif.; and Tyrone, N. Mex.), a tabulation was made, after critical study, summarizing the solar record for the calendar year 1945. These values add another year to the great table of volume 6 of the Annals referred to in last year's report. Progress has also been made in the continued search for possible improvements in solar-constant instrumentation and methods. A new vacuum bolometer, designed by L. B. Clark, technologist of the Observatory, is in preparation. This new design will eliminate the gradual loss of sensitivity which we have noted in the past arising from certain impurities in the vacuum chamber.

Reference was made in last year's report to a contract, signed in June 1945, with the Office of the Quartermaster General, Army Service Forces, under the terms of which the Observatory is to make a detailed study of sun and sky radiation at Camp Lee, Va., as part of extensive tests in progress there to determine the causes for the deterioration of tents and tent fabrics. It is known that radiation from the sun and sky falling upon exposed fabrics over extended periods is a factor which hastens deterioration in the fabrics. Practically nothing is known, however, of the amount of radiation required, nor of the part

of the spectrum most active, in the degradation. The development of suitable instruments and methods for this radiation study at Camp Lee, the installation of the equipment, and the organization of the observing program occupied the time of most of the staff for several months. The type of instrument adopted is a special form of the sensitive, quick-acting thermoelement which Mr. Clark has developed and used in many lines of research. Eight copies of this instrument, all automatically recording, were prepared under Mr. Clark's direction, and are now in successful operation at Camp Lee. Special glass filters, hemispherical in shape, are used to restrict the instrument to the measurement of radiation in known parts of the spectrum. Description of these instruments is given in a report soon to be issued.

Dr. Abbot has continued his researches correlating solar activity with weather changes, and has published two articles on the subject during the year.

Publication of Dr. Arctowski's studies of terrestrial and solar atmospheric circulation has been delayed. Dr. Arctowski has uncovered certain interesting phases of the subject which he feels require further study.

Work in the field.—Notwithstanding the continued handicap of manpower shortage, observations were made on every available day at all three field stations until February 1946. At that time the Tyrone station was closed because of the resignation of S. C. Warner as director. Since the sky conditions at Tyrone have been progressively less favorable during the past 4 years, probably owing to increased smoke and dust from mining operations in the general vicinity, the closing of this station is not too greatly regretted. At the end of the fiscal year arrangements were nearly completed to install the Tyrone equipment temporarily at a wet, sea-level location in Florida where valuable observations can be made concerning the transmission of radiation through water vapor and related problems.

The program of observations of sun and sky radiation at Camp Lee, Va., begun in December 1945, is still in progress. The observations are made largely by personnel of the Quartermaster Board working under the direction of Mr. Hoover. This has necessitated frequent trips by Mr. Hoover to Camp Lee to install, supervise, and inspect the work. From these Camp Lee measurements, a great volume of information is accumulating concerning the kind and amount of radiation, for each hour of each day, that falls upon the tents and exposed panels. These data will be summarized and published at intervals. The first report is expected to appear shortly. It is confidently hoped that these measurements will help to explain the causes of exposed fabric deterioration.

In August 1945 Dr. Abbot spent several weeks at Mount Wilson, Calif., testing his new radiometer and developing plans for improved apparatus for measuring the energy spectra of stars.

(2) DIVISION OF RADIATION AND ORGANISMS

(Report prepared by Dr. Earl S. Johnston, Assistant Director of the Division)

Project 1. Photosynthesis.—For the accurate determination of carbon dioxide absorbed by green plants in the process of photosynthesis it is necessary to correct for the amount of carbon dioxide eliminated in respiration. Before many of the fundamental problems arising in this study can be solved it is absolutely necessary to improve the accuracy of the apparatus designed for the measurements of minute changes in the concentration of carbon dioxide surrounding the plant. During the past year much time has been given to this work and many experiments carried out. Respiration experiments have been run with barley seedlings, and small animals such as the cockroach, cricket, and grasshopper. A most interesting and unexplained respiration rhythm has been discovered in the cockroach. However, this phenomenon as well as an apparent water-vapor effect cannot be fully explained until more work is completed on this delicate and highly sensitive apparatus.

Project 2. Plant growth.—The study of plant growth under controlled artificial conditions of mineral nutrition, illumination, temperature, and humidity has been continued. The experiments carried out on wave-length balance indicated a need for improvement in the technique used. Further work along this line is being pursued.

Most of the work under this general project has centered around the problem of the role of the environment in the growth processes of cereal seedlings. The effects of radiation, which constitute the primary problem, have been found to depend upon other environmental factors, such as temperature, water supply, humidity, and chemical composition of substrate so that it has become necessary to evaluate the importance of these. Some of the observations and tentative conclusions from these as yet incomplete experiments are listed:

a. Development of seedling as a whole.—In the growth processes of grass seedlings a sharp distinction must be made between the rate of growth and the ultimate amount of growth. These two properties appear to be antagonistic in the sense that the slower the rate of development of a given organ, the longer does growth continue and the greater is the final size attained.

The rate of water absorption appears to be a determining factor in controlling the growth processes; the effects of certain other environ-

mental factors can be interpreted as resulting from an influence upon the water uptake.

b. Growth of coleoptile.—A marked effect of temperature upon the growth inhibition of the oats coleoptile by light has been observed. Below 25° C. the inhibition is independent of temperature; between 25° and 30° the inhibition effect becomes smaller as the temperature increases; above 30° there is no inhibition and possibly a slight stimulation by light. These statements apply, of course, only to the specific conditions of intensity and wave length which have been studied. An improved thermostat is being constructed so that the experiments can be extended with greater precision.

c. Root.—A very interesting effect of light upon root growth has been noted. Roots which are caused, by mechanical restraint, to grow in a horizontal direction elongate at their normal rate in darkness, but are greatly inhibited by light. In addition to the interest in the mechanism by which this result might be caused, it is noted that red light is effective, indicating the presence of a pigment which absorbs these wave lengths.

d. Cells.—Histological studies of the mesocotyl have been initiated in order to correlate the gross effects with the cellular development of this organ.

e. Technique.—In cultures of seedlings at high humidity and temperature a complication is introduced by the abundant development of molds. Considerable time has been devoted to devising techniques for inhibiting mold growth without influencing the development of the higher plants. As the result of tests with about 200 fungicidal chemicals a few have been found which appear promising. Sterilization by ultraviolet irradiation also has been found effective.

PERSONNEL

On March 9, 1946, the Observatory lost by death Lyman A. Fillmen, instrument maker for the past 15 years. His place was filled on April 8, 1946, by Darnel G. Talbert.

A. G. Froiland, on military furlough since July 8, 1943, returned as astrophysical aid November 16, 1945. In February 1946 he was promoted to associate astrophysicist and transferred to Montezuma, Chile, where he assumed charge of the Montezuma station, replacing F. A. Greeley. Mr. Greeley returned to Washington in May, and at the close of the fiscal year was enjoying a well-earned vacation. He and Mrs. Greeley had for 3 years carried on the arduous work of the Chilean station unaided.

In September 1945 A. F. Moore, director of the Tyrone station, exchanged stations with S. C. Warner, director of the Table Mountain

station. In January 1946 Mr. Warner resigned to return to the teaching profession.

PUBLICATIONS

During the fiscal year the following publications on the work of the Observatory appeared:

ABBOT, C. G., Correlations of solar variation with Washington weather. Smithsonian Misc. Coll., vol. 104, No. 13, July 1945.

ABBOT, C. G., 1945-1946 report on the 27.0074-day cycle in Washington precipitation. Smithsonian Misc. Coll., vol. 104, No. 21, March 1946.

ABBOT, C. G., Energy spectra of stars. Smithsonian Misc. Coll., vol. 104, No. 22, April 1946.

ABBOT, C. G., HOOVER, W. H., and CLARK, L. B., A sensitive radiometer. Smithsonian Misc. Coll., vol. 104, No. 14, August 1945.

ALDRICH, L. B., The solar constant and sunspot numbers. Smithsonian Misc. Coll., vol. 104, No. 12, July 1945.

Respectfully submitted.

L. B. ALDRICH, *Director.*

DR. A. WETMORE,

Secretary, Smithsonian Institution.

APPENDIX 9

REPORT ON THE LIBRARY

SIR: I have the honor to submit the following report on the activities of the Smithsonian library for the fiscal year ended June 30, 1946:

As the fiscal year 1945-1946 drew to a close, the library, as an organic part of the Smithsonian Institution, approached the hundredth anniversary of its founding on August 10, 1846, for service in "the increase and diffusion of knowledge among men."

To anyone to whom books are a perpetual source of exciting revelation of human experience and accomplishment, and of the working of men's minds, a backward glance at the hundred years of the library's history furnishes the outline for a richly colored picture of books in use in advancing the boundaries of knowledge. Section 8 of the Act of Organization provided for "the gradual formation of a library composed of valuable works pertaining to all departments of human knowledge," and although this universality of aim was later modified, of necessity, the continuity of purpose in procuring "a complete collection of the memoirs and transactions of learned societies throughout the world" has never been broken. The collection of this and similar important material, begun with the founding of the Institution and now forming part of the Smithsonian Deposit in the Library of Congress, has not been surpassed for size and completeness in the library world, while the working libraries built up at the Institution to serve immediately the Government bureaus it administers include many exceptionally rich collections of material on special subjects.

But even a hundred years ago, the acquisition of books alone was not the whole concern of the Institution in forming its library. Secretary Henry was keenly interested in making it "a center of bibliographical knowledge" as well, and the first librarian, Charles C. Jewett, a man in advance of his time, was a pioneer in proposing and devising the schemes for cooperative cataloging which, as later developed, have done so much to facilitate both the scholarly and the popular use of libraries. He early recognized what the late Lord Rayleigh put so well when, many years later, in an address before the British Association for the Advancement of Science, he said, "By a fiction as remarkable as any to be found in law, what has once been published * * * is usually spoken of as 'known' and it is often forgotten that

the rediscovery in the library may be a more difficult and uncertain process than the first discovery in the laboratory."

The importance of making this "rediscovery in the library" easy for serious students was never so urgently impressed upon librarians as during the late war, when libraries were overrun by research workers from the war agencies. Then as never before did both the excellencies and the deficiencies of library cataloging and of reference and bibliographical services come to light. Just how large a part books played in winning the war it is impossible to say, but many a tale could be told of the finding of a fact which, like the proverbial horseshoe nail in reverse, helped make victory possible. The Smithsonian library is gratified that it was so extensively used by the war agencies. It, in turn, received no small benefit from the experience gained in serving them, which is of especial value in making constructive plans for the improvement of its catalog and for the betterment of its service in general.

VJ-day, coming as it did early in the fiscal year, made the year's history one of conversion to the postwar activities of rehabilitation. Before the war was over, publications had already begun to come in from the liberated countries in Europe, and as the year advanced and shipping conditions improved, more and larger shipments of material that had accumulated abroad arrived. Through the International Exchange Service, 4,937 pieces were delivered to the library, in comparison with 540 received the previous year.

The accessions division recorded the receipt of 37,143 pieces altogether, an increase of more than 11,000 over the year before. In accordance with routine procedure, all documents, dissertations, and other publications not immediately pertinent to the work of the Institution were sent directly to the Library of Congress and there were 9,162 of these, while the total number of volumes and parts cataloged or entered for the Smithsonian Deposit was 5,016.

Among the 1,303 purchased books there were a number of out-of-print works which are noteworthy not so much for their rarity as because they filled some special gap in the collections. A few of them were: *The Game-birds and Water-fowl of South Africa*, by Boyd R. Horsbrugh, 1912; *Etching, an Outline of its Technical Processes and its History . . .*, by Sylvester R. Koehler, 1885; *Miniatures des Cinq Siècles*, 1920; *A History of British Birds*, by Francis O. Morris, 8 volumes, 1863-67; *Icones Filicum Japoniae*, by Masasuke Ogata, 7 volumes, 1928-36; *A Voyage in the South Seas, in the Years 1812, 1813, and 1814*, by Capt. David Porter, of the American Frigate, the *Essex*, 1823; *Anders Zorn, Aquafortiste*, by Axel L. Romdahl, 1923; *Handbuch der Entomologie*, by Christoph W. M. Schröder, 3 volumes, 1925-

29; *A Brief History of Old English Porcelain and its Manufactories . . .*, by Louis M. E. Solon, 1903; *Travels of the Jesuits, into Various Parts of the World: particularly China and the East-Indies . . .* Translated from the celebrated *Lettres édifiantes & curieuses . . .* To which is now prefixed, an *Account of the Spanish Settlements, in America*, with a general index to the whole work, by Mr. Lockman, 2d ed., 2 volumes, 1762; *American Lace and Lace Makers*, by Mrs. Emily Noyes Vanderpoel, edited by Elizabeth C. Barney Buel, 1924; *Arcana Entomologica*, by John Obadiah Westwood, 1845; *A Voyage Round the World, in the Years MDCCXL, I, II, III, IV*, by George Anson, esq; now Lord Anson, Commander in Chief of a Squadron of His Majesty's Ships, sent upon an Expedition to the South-Seas. Compiled from his Papers and Materials, by Richard Walter . . . 5th ed., 1749.

Gifts received were even more numerous than in the preceding year and numbered 4,103, exclusive of the Gilmore collection on vertebrate paleontology which arrived late in the year and has not yet been completely counted. Mrs. Gilmore's gift to the National Museum of the late Dr. Charles W. Gilmore's private library on the subject of his special studies is an important one. Its 600 volumes and especially its hundreds of reprints and separates are invaluable to the work of the division of vertebrate paleontology where it will be housed as a part of the division's sectional library.

To the many other donors of useful books and papers the library is most grateful. Coming as they do from friends of the Institution all over the world they often supply needs in the collections that it would be otherwise difficult to fill.

Toward the close of the fiscal year the Institution was so fortunate as to receive by transfer from the National Academy of Sciences about 850 parts of valuable old scientific serial publications needed for the completion of sets in the Astrophysical Observatory and the Museum libraries and to fill other lacunae in the collections.

With the reestablishment of interrupted exchange relationships all over the world came also the opportunity to share in the rehabilitation of destroyed libraries. Several thousand pieces were withdrawn for this purpose from the library's very large collection of duplicate serial parts, some 1,800 of them in response to specific requests from individual libraries for certain titles, but most of them to be used in combination with similar materials from other libraries collected and to be distributed by the American Book Center for War Devastated Libraries. It would be possible to do more of this very gratifying but time-consuming work, as well as other much-needed work with the duplicates, if the library staff were large enough so that a competent

member, with suitable assistance, could be put in full-time charge of the collections. The duplicates have never been fully organized nor thoroughly studied. They include much material that would be valuable in arranging special exchanges with other libraries for comparable material. Since the termination of the WPA project under which an excellent beginning of their proper sorting and filing was made, it has not been possible to continue any systematic work on them, and the large annual additions that are made to the collections are almost wholly unarranged.

The cataloging of purchased publications and of most of the other currently received material was well kept up, but there was little opportunity to make additions to the union catalog of records of the older publications belonging to the bureau libraries, and none to make progress in reducing the huge "backlog" of incompletely or inaccurately cataloged books. The inadequacy and incompleteness of the catalogs in leading quickly to the information in the older material in the library was distressingly obvious during the war. The cataloging problem is a serious one, and the only satisfactory solution of it would seem to be to make it a special project organized and planned to be completed by a staff especially engaged to do it within a given period of time.

Changes in the library's personnel were the resignation of Mrs. Margaret L. O'Keef on November 2, 1945, and the appointment of Miss Lillian Treder to succeed her on June 17, 1946.

The most urgent of the library's needs continues to be more and better-arranged shelf room. The present overcrowding is extremely serious everywhere, and in the Natural History Building, current accessions can only be shelved by removing older publications and sending them to the inconveniently located and scattered bits of shelf space available in the attic stacks of the Arts and Industries Building. Both the books and the library service suffer badly from such an arrangement. The questions of the library's housing throughout the Institution, and of its cataloging, taken together, have grown to constitute what amounts to a reorganizational problem. The opening year of the Institution's second century would seem to be a most suitable time to look for its solution.

SUMMARIZED STATISTICS

Accessions

	Volumes	Total recorded volumes June 30, 1946
Astrophysical Observatory (including Radiation and Organisms)	205	11,920
Bureau of American Ethnology	109	34,314
Freer Gallery of Art	215	21,697
National Collection of Fine Arts	414	10,569
National Museum	2,772	236,316
National Zoological Park	21	4,142
Smithsonian Deposit at the Library of Congress	1,257	577,430
Smithsonian office	285	31,965
Total	5,278	928,353

Neither incomplete volumes of periodicals nor separates and reprints from periodicals are included in these figures.

Exchanges

New exchanges arranged	262
91 of these were assigned to the Smithsonian Deposit.	
Specially requested publications received	6,259
891 of these were obtained to fill gaps in the Smithsonian Deposit sets.	

Cataloging

Volumes and pamphlets cataloged	6,124
Cards added to catalogs and shelf lists	25,326

Periodicals

Periodical parts entered	12,947
Of these 3,399 were sent to the Smithsonian Deposit.	

Circulation

Loans of books and periodicals	10,223
This figure does not include the very considerable intramural circulation of books and periodicals assigned to sectional libraries for filing, of which no count is kept.	

Binding

Volumes sent to the bindery	840
Volumes repaired in the Museum	1,010

Respectfully submitted.

LEILA F. CLARK, *Librarian.*

Dr. ALEXANDER WETMORE,
Secretary, Smithsonian Institution.

APPENDIX 10

REPORT ON PUBLICATIONS

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution and the Government branches under its administrative charge during the year ended June 30, 1946.

The Institution published during the year 16 papers in the Smithsonian Miscellaneous Collections, 1 Annual Report of the Board of Regents and pamphlet copies of 23 articles in the Report appendix, 1 Annual Report of the Secretary, 2 special publications, and a reprint of 1 special publication.

The United States National Museum issued two Annual Reports, 6 Bulletins, and 5 Proceedings papers.

The Bureau of American Ethnology issued 1 Annual Report, 1 Bulletin, 2 volumes of a five-volume Bulletin, and 1 publication of the Institute of Social Anthropology.

The National Collection of Fine Arts issued one catalog.

The Freer Gallery of Art issued one pamphlet.

Of the publications there were distributed 129,750 copies, which included 148 volumes and separates of Smithsonian Contributions to Knowledge, 29,257 volumes and separates of Smithsonian Miscellaneous Collections, 24,675 volumes and separates of Smithsonian Annual Reports, 18,990 War Background Studies, 2,356 Smithsonian special publications, 45 reports on the Harriman Alaska Expedition, 32,887 volumes and separates of National Museum publications, 12,730 publications of the Bureau of American Ethnology, 1,628 publications of the Institute of Social Anthropology, 10 catalogs of the National Collection of Fine Arts, 5 pamphlets of the Freer Gallery of Art, 16 Annals of the Astrophysical Observatory, 1,056 reports of the American Historical Association, and 5,947 miscellaneous publications not printed by the Smithsonian Institution (mostly Survival Manuals).

SMITHSONIAN MISCELLANEOUS COLLECTIONS

Sixteen papers in this series were issued, as follows:

VOLUME 104

No. 11. The West Atlantic boring mollusks of the genus *Martesia*, by Paul Bartsch and Harald A. Rehder. 16 pp., 3 pls. (Publ. 3804.) July 2, 1945.

No. 12. The solar constant and sunspot numbers, by L. B. Aldrich. 5 pp., 1 fig. (Publ. 3806.) July 2, 1945.

No. 13. Correlations of solar variation with Washington weather, by C. G. Abbot. 10 pp., 5 figs. (Publ. 3807.) July 28, 1945.

No. 14. A sensitive radiometer, by C. G. Abbot, W. H. Hoover, and L. B. Clark. 6 pp., 1 fig. (Publ. 3808.) Aug. 23, 1945.

No. 15. A bibliography and short biographical sketch of William Healey Dall, by Paul Bartsch, Harald Rehder, and Beulah E. Shields. 96 pp., 1 pl. (Publ. 3810.) January 30, 1946.

No. 16. An important new species of oyster from North Borneo suitable for introduction in the Philippines, by Paul Bartsch. 2 pp., 2 pls. (Publ. 3812.) December 12, 1945.

No. 17. New Westville, Preble County, Ohio, meteorite, by E. P. Henderson and S. H. Perry. 9 pp., 4 pls., 1 fig. (Publ. 3814.) January 30, 1946.

No. 18. The skeletal anatomy of fleas (Siphonaptera), by R. E. Snodgrass. 89 pp., 21 pls. (Publ. 3815.) April 1, 1946.

No. 19. Sunspot changes and weather changes, by H. H. Clayton. 29 pp., 23 figs. (Publ. 3816.) March 6, 1946.

No. 20. Schistosomophora in China, with descriptions of two new species and a note on their Philippine relative, by Paul Bartsch. 7 pp., 1 pl. (Publ. 3841.) April 10, 1946.

No. 21. 1945-1946 report on the 27.0074-day cycle in Washington precipitation, by C. G. Abbot. 2 pp. (Publ. 3842.) March 27, 1946.

No. 22. Energy spectra of stars, by C. G. Abbot. 5 pp., 2 figs. (Publ. 3843.) April 10, 1946.

VOLUME 106

No. 3. A list of fresh-water fishes from San José Island, Pearl Islands, Panamá, by Samuel F. Hildebrand. 3 pp. (Publ. 3847.) June 10, 1946.

No. 4. Notes on the herpetology of the Pearl Islands, Panamá, by Doris M. Cochran. 8 pp. (Publ. 3848.) June 24, 1946.

No. 11. Review of the New World species of *Hippodamia* Dejean (Coleoptera: Coccinellidae), by Edward A. Chapin. 39 pp., 22 pls. (Publ. 3856.) June 14, 1946.

No. 12. Descriptions of two new leafbirds from Siam, by H. G. Deignan. 3 pp. (Publ. 3856.) June 24, 1946.

SMITHSONIAN ANNUAL REPORT

Report for 1944.—The complete volume of the Annual Report of the Board of Regents for 1944 was received from the Public Printer December 12, 1945:

Annual Report of the Board of Regents of the Smithsonian Institution showing the operations, expenditures, and condition of the Institution for the year ended June 30, 1944. ix+503 pp., 40 pls., 69 figs. (Publ. 3776.)

The general appendix contained the following papers (Pubs. 3777-3799):

Solar variation and weather, by Charles G. Abbot.

Astronomy in a world at war, by A. Vibert Douglas.

The structure of the universe, by Claude William Heaps.

Industrial science looks ahead, by David Sarnoff.

The new microscopes, by R. E. Seidel and M. Elizabeth Winter.

Radio acoustic ranging (R. A. R.), by Commander K. T. Adams.

The David W. Taylor Model Basin, by Rear Admiral Herbert S. Howard.
Research for aeronautics—its planning and application, by W. F. Farren.
Human limits in flight, by Bryan H. C. Matthews.

Trans-Arctic aviation, by Lt. Elmer Plischke.

Our petroleum resources, by Wallace E. Pratt.

Woods and trees: Philosophical implications of some facts of science, by Frederick H. Krecker.

Biology and medicine, by Asa Crawford Chandler.

The locust plague, by B. P. Uvarov.

The codling moth, by B. A. Porter.

Grassland and farmland as factors in the cyclical development of Eurasian history, by J. Russell Smith.

Southern Arabia, a problem for the future, by Carleton S. Coon.

The New World Paleo-Indian, by Frank H. H. Roberts, Jr.

Easter Island, by Alfred Métraux.

Brain rhythms, by E. D. Adrian.

The development of penicillin in medicine, by H. W. Florey and E. Chain.

Recent advances in anesthesia, by John C. Krantz, Jr.

Aspects of the epidemiology of tuberculosis, by Leland W. Parr.

Report for 1945.—The Report of the Secretary, which included the financial report of the executive committee of the Board of Regents, and which will form part of the Annual Report of the Board of Regents to Congress, was issued January 4, 1946.

Report of the Secretary of the Smithsonian Institution and financial report of the executive committee of the Board of Regents for the year ended June 30, 1945. ix+116 pp., 2 pls. (Publ. 3813.) 1946.

The Report volume for 1945, containing the general appendix, was in press at the close of the year.

SPECIAL PUBLICATIONS

The Smithsonian Institution. 25 pp., 13 pls. (Publ. 3811.) January 14, 1946.
National Aircraft Collection, by Paul Edward Garber. Sixth Edition. 43 pp., illus. (Publ. 3840.) May 31, 1946.

The following special publication was reprinted:

Brief Guide to the Smithsonian Institution. Sixth Edition. 80 pp., illus. 1946.

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM

The editorial work of the National Museum has continued during the year under the immediate direction of the editor, Paul H. Oehser. There were issued 2 Annual Reports, 5 Proceedings papers, and 6 Bulletins.

REPORTS

Report on the progress and condition of the United States National Museum for the year ended June 30, 1944. iii+100 pp. January 5, 1946.

Report on the progress and condition of the United States National Museum for the year ended June 30, 1945. iii+112 pp. June 28, 1946.

PROCEEDINGS: VOLUME 96

No. 3195. *Hyporhamphus patris*, a new species of hemiramphid fish from Sinaloa, Mexico, with an analysis of the generic characters of *Hyporhamphus* and *Hemiramphus*, by Robert R. Miller. Pp. 185-193, fig. 9, pl. 11. July 27, 1945.

No. 3196. Notes on recently mounted reptile fossil skeletons in the United States National Museum, by Charles W. Gilmore. Pp. 195-203, pls. 12-19. February 5, 1946.

No. 3197. The onychophores of Panama and the Canal Zone, by Austin H. Clark and James Zetek. Pp. 205-213. February 21, 1946.

No. 3198. Echiuroid worms of the North Pacific Ocean, by Walter Kenrick Fisher. Pp. 215-292, figs. 10-19, pls. 20-37. April 11, 1946.

No. 3199. The osteology of the fossil turtle *Testudo praestians* Lambe, with notes on other species of *Testudo* from the Oligocene of Wyoming, by Charles W. Gilmore. Pp. 293-310, figs. 20-27, pls. 38-44. March 28, 1946.

BULLETINS

No. 185, part 4. Checklist of the coleopterous insects of Mexico, Central America, the West Indies, and South America, compiled by Richard E. Blackwelder. Pp. 551-763. May 13, 1946.

No. 186. The birds of northern Thailand, by H. G. Deignan. v+616 pp., 4 maps, 9 pls. September 17, 1945.

No. 187. An annotated checklist and key to the snakes of Mexico, by Hobart M. Smith and Edward M. Taylor. iv+239 pp. October 5, 1945.

No. 188. The fresh-water fishes of Siam, or Thailand, by Hugh M. Smith. xi+622 pp., 107 figs., 9 pls. November 13, 1945.

No. 189. A descriptive catalog of the shore fishes of Peru, by Samuel F. Hildebrand. xi+530 pp., 95 figs. February 26, 1946.

No. 190. The North American clear-wing moths of the family Aegeriidae, by George P. Engelhardt. vi+221 pp., 32 pls. (16 in color). June 28, 1946.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY

The editorial work of the Bureau has continued under the immediate direction of the editor, M. Helen Palmer. During the year the following publications were issued:

Sixty-second Annual Report of the Bureau of American Ethnology, 1944-1945. 9 pp.

Bulletin 137. The Indians of the Southeastern United States, by John R. Swanton. 943 pp., 108 pls., 5 figs., 13 maps.

Bulletin 143. Handbook of South American Indians. Julian H. Steward, editor. Volume 1: The Marginal tribes. 624 pp., 112 pls., 69 figs., 7 maps. Volume 2: The Andean civilizations. 1,035 pp., 192 pls., 100 figs., 11 maps.

Institute of Social Anthropology Publ. No. 2. Cherán: A Sierra Tarascan village, by Ralph L. Beals. 225 pp., 8 pls., 19 figs., 5 maps.

NATIONAL COLLECTION OF FINE ARTS

The National Collection of Fine Arts issued one catalog, as follows:

Catalog of American and European paintings in the Gellatly Collection. Third Edition. 20 pp., 11 pls. 1945.

FREER GALLERY OF ART

The Freer Gallery of Art issued one pamphlet, as follows:

The Freer Gallery of Art. Revised Edition. 12 pp., 6 pls., 2 figs. 1945.

REPORT OF THE AMERICAN HISTORICAL ASSOCIATION

The annual reports of the American Historical Association are transmitted by the Association to the Secretary of the Smithsonian Institution and are communicated by him to Congress, as provided by the act of incorporation of the Association. The following report volumes were issued this year:

Annual Report of the American Historical Association for 1944. Vol. 1, Proceedings and Guide to the American Historical Review, 1895-1945; vol. 2, Calendar of the American Fur Company's Papers. Part 1: 1831-1840; vol. 3, Calendar of the American Fur Company's Papers. Part 2: 1841-1849.

The following were in press at the close of the fiscal year: Annual Report for 1943, vol. 2 (Writings on American History); Annual Report for 1945, vol. 1 (Proceedings and list of members); vols. 2, 3, and 4 (Spain in the Mississippi Valley, 1765-1794, Parts 1, 2, and 3).

REPORT OF THE NATIONAL SOCIETY, DAUGHTERS OF THE AMERICAN REVOLUTION

The manuscript of the Forty-eighth Annual Report of the National Society, Daughters of the American Revolution, was transmitted to Congress, in accordance with law, November 7, 1945.

ALLOTMENTS FOR PRINTING

The congressional allotments for the printing of the Smithsonian Annual Reports to Congress and the various publications of the Government bureaus under the administration of the Institution were virtually used up at the close of the year. The appropriation for the coming year, ending June 30, 1947, totals \$88,500, allotted as follows:

Smithsonian Institution.....	\$16, 000
National Museum.....	43, 000
Bureau of American Ethnology.....	17, 480
National Collection of Fine Arts.....	500
International Exchanges.....	200
National Zoological Park.....	200
Astrophysical Observatory.....	500
American Historical Association.....	10, 620
Total.....	88, 500

Respectfully submitted.

W. P. TRUE, *Chief, Editorial Division.*

Dr. A. WETMORE,

Secretary, Smithsonian Institution.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITH- SONIAN INSTITUTION

FOR THE YEAR ENDED JUNE 30, 1946

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds of the Smithsonian Institution, together with a statement of the appropriations by Congress for the Government bureaus in the administrative charge of the Institution.

SMITHSONIAN ENDOWMENT FUND

The original bequest of James Smithson was £104,960 8s. 6d.—\$508,318.46. Refunds of money expended in prosecution of the claim, freights, insurance, etc., together with payment into the fund of the sum of £5,015, which had been withheld during the lifetime of Madame de la Batut, brought the fund to the amount of \$550,000.

Since the original bequest, the Institution has received gifts from various sources, the income from which may be used for the general work of the Institution. These, including the original bequest, plus savings, are listed below, together with the income for the present year.

ENDOWMENT FUNDS

(Income for unrestricted use of the Institution)

Partly deposited in United States Treasury at 6 percent and partly invested in stocks, bonds, etc.

	Investment	Income present year
Parent fund (original Smithson bequest, plus accumulated savings)	\$728, 878. 29	\$43, 701. 53
Subsequent bequests, deposits, and gifts deposited in the United States Treasury		
Fund:		
Annuity, Bequest of Mrs. James Smithson fund	51, 770. 56	2, 155. 51
Endowment, from gifts	315, 455. 63	10, 989. 98
Habel, Dr. S., bequest fund	500. 00	30. 00
Hachenberg, George F. and Caroline, bequest fund	4, 079. 43	142. 08
Hamilton, James, bequest fund	2, 909. 47	164. 26
Henry, Caroline, bequest fund	1, 226. 77	42. 73
Hodgkins, Thomas G. (general) gift	146, 412. 95	8, 019. 25
Rhees, William Jones, bequest fund	1, 069. 87	52. 11
Sanford, George H., memorial fund	2, 002. 96	97. 45
Witherspoon, Thomas A., memorial fund	130, 900. 34	4, 559. 12
Special fund, stock in reorganized closed banks	2, 280. 00	527. 69
Total	658, 607. 98	26, 780. 18
Grand total	1, 387, 486. 27	70, 481. 71

The Institution holds also a number of endowment gifts, the income of each being restricted to specific use. These, plus accretions to date, are listed below, together with income for the present year.

	Investment	Income, present year
Abbott, William L., fund for investigations in biology.....	\$107,456.55	\$3,486.59
Arthur, James, fund for investigations and study of the sun and lecture on same.....	40,566.73	1,412.90
Bacon, Virginia Purdy, fund, for traveling scholarship to investigate fauna of countries other than the United States.....	50,819.13	1,769.97
Baird, Lucy H., fund for creating a memorial to Secretary Baird.....	24,422.02	850.59
Bastow, Frederick D., fund, for purchase of animals for Zoological Park.....	1,014.10	35.32
Canfield Collection fund for increase and care of the Canfield collection of minerals.....	38,795.43	1,351.20
Casey, Thomas L., fund, for maintenance of the Casey collection, and promotion of researches relating to Coleoptera.....	9,303.64	324.04
Chamberlain, Francis Lea, fund, for increase and promotion of Isaac Lea collection of gems and mollusks.....	28,564.24	994.86
Eickemeyer, Florence Brevoort, fund, for preservation and exhibition of the photographic collection of Rudolph Eickemeyer, Jr.....	514.58	17.92
Hillyer, Virgil, fund, for increase and care of Virgil Hillyer collection of lighting objects.....	6,666.45	232.19
Hitchcock, Dr. Albert S., library fund, for care of Hitchcock Agrostological Library.....	1,600.54	55.74
Hodgkins fund, specific, for increase and diffusion of more exact knowledge in regard to nature and properties of atmospheric air.....	100,000.00	6,000.00
Hrdlička, Aleš and Marie, fund, to further researches in physical anthropology and publication in connection therewith.....	18,654.65	649.72
Hughes, Bruce, fund, to found Hughes alcove.....	19,415.74	676.23
Long, Annette and Edith C., fund, for upkeep and preservation of Long collection of embroideries, laces, etc.....	550.78	19.18
Myer, Catherine Walden, fund, for purchase of first-class works of art for the use and benefit of the National Collection of Fine Arts.....	19,227.51	669.67
National Collection of Fine Arts, Julia D. Strong bequest fund, for benefit of National Collection of Fine Arts.....	10,141.81	353.21
Pell, Cornelia Livingston, fund, for maintenance of Alfred Duane Pell collection.....	7,513.73	261.87
Poore, Lucy T. and George W., fund, for general use of the Institution when principal amounts to \$250,000.....	102,126.64	4,228.27
Rathbun, Richard, memorial fund, for use of division of U. S. National Museum containing Crustacea.....	10,788.45	375.73
Reid, Addison T., fund, for founding chair in biology in memory of Asher Tunis.....	30,261.17	1,399.12
Roebbling Collection fund, for care, improvement and increase of Roebbling collection of minerals.....	122,418.63	4,263.71
Rollins, Miriam and William, fund, for investigations in physics and chemistry.....	95,247.10	3,319.23
Smithsonian employees retirement fund.....	80,371.03	2,799.24
Springer, Frank, fund, for care, etc. of Springer collection and library.....	18,189.94	633.54
Walcott, Charles D. and Mary Vaux, research fund, for development of geological and paleontological studies and publishing results thereof.....	430,925.04	14,746.52
Younger, Helen Walcott, fund, held in trust.....	50,125.70	2,513.81
Zerbee, Frances Brincklé, fund, for endowment of aquaria.....	962.14	33.51
Total.....	1,426,648.47	53,473.88

The above funds amount to a total of \$2,814,134.74 and are carried in the following investment accounts of the Institution:

United States Treasury deposit account, drawing 6 percent interest.....	\$1,000,000.00
Consolidated investment fund (income in table below).....	1,551,671.40
Real estate, mortgages, etc.....	203,010.79
Special funds, miscellaneous investments.....	51,908.70
Uninvested capital.....	7,543.85
Total.....	2,814,134.74

CONSOLIDATED FUND

This fund contains substantially all the investments of the Institution, with the exception of those of the Freer Gallery of Art; the deposit of \$1,000,000 in the United States Treasury, with guaranteed income of 6 percent; and investments in real estate and real-estate mortgages. This fund contains endowments for both unrestricted and specific use. A statement of principal and income of this fund for the last 10 years follows:

Fiscal year	Principal	Income	Percent- age	Fiscal year	Principal	Income	Percent- age
1937-----	\$738,858.54	\$33,819.43	4.57	1942-----	\$1,270,968.45	\$46,701.98	3.67
1938-----	867,528.50	34,679.64	4.00	1943-----	1,316,533.49	50,524.22	3.83
1939-----	902,801.27	30,710.53	3.40	1944-----	1,372,516.41	50,783.79	3.69
1940-----	1,081,249.25	38,673.29	3.47	1945-----	1,454,957.73	50,046.67	3.50
1941-----	1,093,301.51	41,167.38	3.76	1946-----	1,559,215.25	57,612.38	3.69

CONSOLIDATED FUND

Gain in investments over year 1945

Investments made from gifts and savings on income-----	\$82,817.37
Investments of gain from sales, etc., of securities-----	21,440.15
Total-----	104,257.52

FREER GALLERY OF ART FUND

Early in 1906, by deed of gift, Charles L. Freer, of Detroit, gave to the Institution his collection of Chinese and other Oriental objects of art, as well as paintings, etchings, and other works of art by Whistler, Thayer, Dewing, and other artists. Later he also gave funds for the construction of a building to house the collection, and finally in his will, probated November 6, 1919, he provided stock and securities to the estimated value of \$1,958,591.42, as an endowment fund for the operation of the Gallery.

The above fund of Mr. Freer was almost entirely represented by 20,465 shares of stock in Parke, Davis & Co. As this stock advanced in value, much of it was sold and the proceeds reinvested so that the fund now amounts to \$5,994,394.31 in a selected list of securities classified later.

The invested funds of the Freer bequest are under the following headings:

Court and grounds fund-----	\$671,519.80
Court and grounds maintenance fund-----	168,643.43
Curator fund-----	683,381.72
Residuary legacy fund-----	4,470,849.36
Total-----	5,994,394.31

Statement of principal and income for the last 10 years

Fiscal year	Principal	Income	Percent- age
1937.....	\$4,881,986.96	\$280,969.53	5.75
1938.....	4,820,777.31	255,651.61	5.30
1939.....	5,075,976.76	212,751.78	4.19
1940.....	6,112,953.46	242,573.92	3.96
1941.....	6,030,586.91	233,079.22	3.86
1942.....	5,912,878.64	241,557.77	4.08
1943.....	5,836,772.01	216,125.07	3.70
1944.....	5,881,402.17	212,395.27	3.61
1945.....	5,864,061.73	212,552.69	3.62
1946.....	5,994,394.31	220,818.86	3.68

FREER FUND

Gain during present year from sale, call of securities, etc.----- \$130,332.58

SUMMARY OF ENDOWMENTS

Invested endowment for general purposes----- \$1,387,486.27
 Invested endowment for specific purposes other than Freer endowment ----- 1,426,648.47

Total invested endowment other than Freer endowment... 2,814,134.74
 Freer invested endowment for specific purposes----- 5,994,394.31

Total invested endowment for all purposes----- 8,808,529.05

CLASSIFICATION OF INVESTMENTS

Deposited in the U. S. Treasury at 6 percent per annum, as authorized in the United States Revised Statutes, sec. 5591----- \$1,000,000.00

Investments other than Freer endowment (cost or market value at date acquired):

Bonds (18 different groups)----- \$627,612.34
 Stocks (51 different groups)----- 975,967.76
 Real estate and first-mortgage notes----- 203,010.79
 Uninvested capital----- 7,543.85

1,814,134.74

Total investments other than Freer endowment----- 2,814,134.74

Investment of Freer endowment (cost or market value at date acquired):

Bonds (29 different groups)----- 2,962,710.30
 Stocks (53 different groups)----- 2,983,576.38
 Real estate first-mortgage notes----- 2,500.00
 Uninvested capital----- 45,607.63

5,994,394.31

Total investments----- 8,808,529.05

CASH BALANCES, RECEIPTS, AND DISBURSEMENTS DURING FISCAL
YEAR 1946¹

Cash balance on hand June 30, 1945----- \$760,218.09

Receipts:

Cash income from various sources for general work of the Institution-----	\$93,441.46	
Cash gifts and contributions expendable for special scientific objects (not for investment) -	30,627.29	
Cash income from endowments for specific use other than Freer endowment and from miscellaneous sources (including refund of temporary advances)-----	192,425.47	
Cash capital from sale, call of securities, etc. (for investment)-----	350,519.70	
Total receipts other than Freer endowment-----		667,013.92
Cash income from Freer endowment-----	\$220,818.86	
Cash capital from sale, call of securities, etc. (for investment)-----	1,599,813.00	
Total receipts from Freer endowment-----		1,820,631.86
Total-----		<u>3,247,863.87</u>

Disbursements:

From funds for general work of the Institution:		
Buildings—care, repairs, and alterations-----	\$3,108.43	
Furniture and fixtures-----	63.75	
General administration-----	27,109.04	
Library-----	2,989.55	
Publications (comprising preparation, printing and distribution)-----	14,995.12	
Researches and explorations-----	21,888.11	
		70,154.00

From funds for specific use other than Freer endowment:

Investments made from gifts and from savings on income-----	82,817.37	
Other expenditures, consisting largely of research work, travel, increase and care of special collections, etc., from income of endowment funds, and from cash gifts for specific use (including temporary advances)-----	132,745.71	
Reinvestment of cash capital from sale, call of securities, etc-----	347,920.79	
Cost of handling securities, fee of investment counsel, and accrued interest on bonds purchased-----	3,303.45	
		566,787.32

From Freer endowment:

Operating expenses of the Gallery, salaries, field expenses, etc-----	68,366.75
Purchase of art objects-----	114,070.23

¹ This statement does not include Government appropriations under the administrative charge of the Institution.

Disbursements—Continued

From Freer endowment—Continued

Reinvestment of cash capital from sale, call of securities, etc.....	\$1,595,344.67
Cost of handling securities, fee of invest- ment counsel, and accrued interest on bonds purchased.....	25,730.45
	<hr/> \$1,803,512.10
Cash balance June 30, 1946.....	807,410.45
Total	<hr/> 3,247,863.87

Included in the above receipts was cash received as royalties from sales of Smithsonian Scientific Series to the amount of \$26,498.52. This was distributed as follows:

Smithsonian Institution Endowment Fund.....	\$11,753.71
Smithsonian Institution Emergency Fund.....	2,938.42
Smithsonian Institution Unrestricted Fund, General.....	8,815.28
Salaries	2,991.11
	<hr/> 26,498.52

Included in the foregoing are expenditures for researches in pure science, publications, explorations, care, increase, and study of collections, etc., as follows:

Expended from general funds of the Institution:

Publications	\$14,995.12
Researches and explorations.....	21,888.11
	<hr/> \$36,883.23

Expenditures from funds devoted to specific purposes:

Researches and explorations.....	40,495.84
Care, increase, and study of special collections.....	5,586.81
Publications	4,184.80
	<hr/> 50,267.45
Total	<hr/> 87,150.68

The practice of depositing on time in local trust companies and banks such revenues as may be spared temporarily has been continued during the past year, and interest on these deposits has amounted to \$739.72.

The Institution gratefully acknowledges gifts or bequests from the following:

Audrey H. Madden, for "Northern Mexico Archeological Fund," to further archeological investigations in Mexico.

National Academy of Sciences and Social Science Research Council, for "Committee for the Recovery of Archeological Remains."

Research Corporation, for printing "Smithsonian Elliptic Functions Tables," by G. W. Spenceley.

John A. Roebing, as a further contribution for research in radiation.

All payments are made by check, signed by the Secretary of the Institution on the Treasurer of the United States, and all revenues are deposited to the credit of the same account. In many instances deposits are placed in bank for convenience of collection and later are withdrawn and deposited in the United States Treasury.

The foregoing report relates only to the private funds of the Institution.

The following appropriations were made by Congress for the Government bureaus under the administrative charge of the Smithsonian Institution for the fiscal year 1946:

Salaries and expenses.....	\$1,357,561.00
National Zoological Park.....	375,670.00

In addition, funds were transferred from other Departments of the Government for expenditure under direction of the Smithsonian Institution:

Cooperation with the American Republics (transfer from State Department)	\$98,488.00
Working Fund, transferred from National Park Service, Interior Department, for archeological investigations in Missouri River Basin.....	20,000.00
Working Fund, transferred from Navy Department, for Crossroads Project	12,920.00

The report of the audit of the Smithsonian private funds is given below:

SEPTEMBER 26, 1946.

EXECUTIVE COMMITTEE, BOARD OF REGENTS,

Smithsonian Institution, Washington, D. C.

SIRS: Pursuant to agreement we have audited the accounts of the Smithsonian Institution for the fiscal year ended June 30, 1946, and certify the balances of cash on hand, including petty cash fund, June 30, 1946, to be \$800,310.45.

We have verified the records of receipts and disbursements maintained by the Institution and the agreement of the book balances with the bank balances.

We have examined all the securities in the custody of the Institution and in the custody of the banks and found them to agree with the book records.

We have compared the stated income of such securities with the receipts of records and found them in agreement therewith.

We have examined all vouchers covering disbursements for account of the Institution during the fiscal year ended June 30, 1946, together with the authority therefor, and have compared them with the Institution's record of expenditures and found them to agree.

We have examined and verified the accounts of the Institution with each trust fund.

We found the books of account and records well and accurately kept and the securities conveniently filed and securely cared for.

All information requested by your auditors was promptly and courteously furnished.

We certify the balance sheet, in our opinion, correctly presents the financial condition of the Institution as at June 30, 1946.

WILLIAM L. YAEGER,
Certified Public Accountant.

Respectfully submitted.

FREDERIC A. DELANO,
VANNEVAR BUSH,
CLARENCE CANNON,
Executive Committee

GENERAL APPENDIX
TO THE
SMITHSONIAN REPORT FOR 1946

ADVERTISEMENT

The object of the **GENERAL APPENDIX** to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution from a very early date to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and, during the greater part of its history, this purpose has been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, induced in part by the discontinuance of an annual summary of progress which for 30 years previously had been issued by well-known private publishing firms, the Secretary had a series of abstracts prepared by competent collaborators, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1946.

ON THE ASTRONOMICAL DATING OF THE EARTH'S CRUST¹

BY HARLOW SHAPLEY

Harvard University, Cambridge, Mass.

These notes on cosmogony are only minor contributions in an important and expanding theme. Over the years a considerable number of scientists are gradually developing a fairly complete and satisfying cosmogony. When the hypotheses settle down into accepted laws, and the skimpy observations grow into "facts of the world," my present contribution will avail little; but at this particular moment, it may show the trend of our thinking and planning.

Until recently, the word cosmogony generally implied, astronomically, the study of the origin of the earth and of the other planets;² scientific thoughts about the universe had of necessity been restricted closely to the planetary system, with an occasional vague adventure into the unexplored realm of stellar bodies. But as our knowledge of stars and nebulae increased, this vagueness diminished; and, with a fine disregard for our impotence, we have now tackled the origins of stars, star clusters, nebulae, galaxies, and space-time itself. Cosmogony has appropriately expanded beyond the bounds of the solar system, and now includes the description and theory of the whole knowable material universe. As something of a digression, it examines the riddles of the origin of planetary systems. But perhaps this appearance of implied condescension toward earthly affairs is inappropriate, for the more we look into the problems of the origin of the earth, the more we find that its genesis involves operations that are universal. The earth's crust, it appears, has an age not at all insignificant compared with the duration of stellar processes; and the chemistry of the earth's crust is a convenient and comprehensive sample of the chemistry of the universe.

¹ Paper No. 90, published under the auspices of the committee on research in experimental geology and geophysics and the division of geological sciences at Harvard University. Reprinted by permission from the American Journal of Science, vol. 243-A, Daily Volume, 1945.

² To many writers, cosmology is a preferred synonym, notwithstanding its frequent discoloration with metaphysics; and cosmography is a proper and modest substitute when simple description of cosmic matters is concerned.

Eddington has pointed out that with our new knowledge of a new physics we might have predicted the existence of the stars from the general properties of matter, even if we had been hopelessly cloud-bound and had never seen them. The atomically small leads directly to the sidereally immense. Analogously, we could now propose half a dozen problems dealing directly with the local solar system, the solution of which would go far toward settling the most basic problems of universal cosmogony.

The preceding remarks are prefatory to the observation that an astronomer who is especially interested in the macrocosmos is in congenial company when he associates with a geologist who explores the origin of meteorites, the topography of the moon, and the atmosphere of planets, and writes on such subjects as "Our Mobile Earth"³ and "The Strength and Structure of the Earth."⁴

HOT GAS AND COLD SPACE

A factor of high importance in general cosmogony, as well as in the contemplation of the surface rocks of the earth, is the greediness with which interstellar space sucks the life blood out of the stars. Or to put the same idea in prosaic and less anthropomorphic terms, the second law of thermodynamics, which records that heat flows in the direction of lower temperature, is a most basic principle in sidereal evolution.

The temperature of interstellar space is a little above absolute zero; the temperature of the stars, except in their relatively thin and cool atmospheric blankets, is in the tens of millions of degrees absolute. Hence the stars cool off violently. The violence is not perceptible to the average observer, unless he be equipped with long-range cosmic vision and competent theory. But the astonishing rate with which our own star pours its heat into the vacuum of interstellar space would scarcely permit time for the evolution of the observer and his ancestral line of living forms, if it were not for the existence of a mechanism for the subatomic replacement of the heat so profusely radiated. In a few scores of millions of years the heat of an average star would be disastrously diminished—disastrous for neighboring protoplasmic life—if the expenditure were not prolonged a thousandfold by the "carbon stove" mechanism, which burns stellar hydrogen fuel into helium ash while liberating energy, and by similar atomic transformations.⁵

³ Daly, R. A., 1926. Scribner's, New York.

⁴ Daly, R. A., 1940. Prentice-Hall, New York.

⁵ Nontechnical accounts of these atomic transformations can be found in Gamow, *The birth and death of the sun*, The Viking Press, New York, 1940; and Russell, *Sci. Amer.*, vol. 161, pp. 18-19, 1939.

The temperature of interstellar or intergalactic space can be variously defined. When measured by the equilibrium temperature of a small meteoritic particle at a distance of a light-year or more from the nearest luminous star, it is probably but 2 or 3 degrees above absolute zero. But if we should "measure" temperature in terms of atomic and molecular motion, we could say that a radiant gaseous nebula (even though of almost infinitesimal rarity) at the distance of a light-year from a blue star has a temperature of $10,000^{\circ}$ or $20,000^{\circ}$ absolute.

The first definition is the one to choose in considering the leakage or radiation from the surface of the sun, a leakage of 4,000,000 tons of light per second. The sun's output of light would be enormously greater if we should peel off suddenly the outer 1 percent of its body. The skinning of the sun would expose highly ionized gases with temperatures in the millions of degrees. We would have a kind of supernova, but only momentarily on cosmic time scale; for promptly the ionized atoms would regain their shells of electrons, some molecules would form, the present heavily absorbing atmospheric layers would re-form, and with some serious convulsions and oscillations set up by the sudden exposure, the sun nova would speedily return toward the calm equilibrium it enjoyed before we ventured the reckless experiment.

It is quite likely that great gaseous envelopes might be produced by a sun-to-nova flare-up, or in course of the subsequent convulsions; and in any case, the earth and neighboring planets would be promptly scorched clean of biology and their surface features melted away. Clearly the sun has not been a nova since the freezing of the earth's surface into its present state.

These comments on the coldness of space and on the sub-surface hotness of the sun are all immediately relevant to the problems of the origin of the earth's rocky crust. If the planets were generated catastrophically from the sun, much of the material composing them must once have been this highly superheated material that lies not far below the $6,000^{\circ}$ surface layers through which our present sunlight is filtered and cooled; we must use not the relatively cool outer portions alone, for the total mass of the sun's atmosphere is small compared with the mass of a planet.

The greediness with which interstellar space, even interplanetary space, absorbs radiation is significant in its bearing on the age of the earth's crust. Both elementary consideration and mathematical calculations indicate that any earth-sized gaseous or liquid body, isolated in sidereal space, would freeze into solid matter (rocks) practically instantaneously—again in terms of cosmic time scales.

It is this quick transition from the normal, hot, ionized, turbulent, gaseous state of stellar matter to the relatively cold, dead, crusted body of a small or medium-sized planet that is important in bringing to-

gether the cosmic-minded geologist and the astronomer. For it means that the rocky surface of the earth is essentially coeval with the planetary system. The measurement of the ages of the oldest rocks is therefore a measurement also of the total duration of the earth. The astronomer sees little support for the suggestion that all the planets may have not been born together. Planetary birth is probably such a catastrophic affair that if a second family were produced the violence would wreck all preexisting systems of planets and satellites.

We owe the concept and analysis of the high-speed cooling of the original surface of a disruption-produced earth to Harold Jeffreys, whose attack on cosmogony has been from the standpoint of geophysics.

It is worth emphasizing again that the earth is a sidereal body of really great antiquity. We shall see later that there is good evidence for believing that the pre-Cambrian rocks of our countryside have existed, many of them unchanged, throughout most of the history of the Pleiades, the Milky Way, and the expanding universe. And it is additional good fortune that during the past thousand million years there has been left a fairly continuous record of living forms on this ancient crust; that continuity of organisms, and especially the characteristics of plant forms for two or three hundred million years, provides the astronomer with his best evidence on the stability of remote stars. Indeed, the fossil plants, in the sediments dated by radioactive processes, have inspired and practically forced our search for heat-generating atomic transformations within the stars.* These fossils prove the essential constancy of the intensity and quality of solar radiation throughout geological time. Many fertile and successful astronomical theories would probably still remain unformulated if, instead of the paleontological record of the earth's surface, we had a dictum dating organisms, for instance, from only 4000 B. C.

NOTE ON SEVERAL COSMOGONIC FAILURES

The astronomers and geologists who have worked assiduously during the past half century on the theory of the origin of the earth have reason to be sincerely satisfied with themselves because they have produced so many hypotheses that do not work. By showing what is not so, not sufficient, not compatible with the growing body of verifiable observations, they have cleared the field for more competent theoretical investigations and indicated in what direction profitable astronomical and mathematical researches may lie.

A serious hindrance to the formulation of any planetary-system cosmogony that may be even temporarily successful is the abundance

* Shapley, H., *The age of the earth*, Publ. Astron. Soc. Pacific, October 1918.

of our clues to the mystery. We know too much to permit any naïve hypothesis to prosper.

A successful theory must account reasonably well for the following 10 circumstances (the number could be much increased):

1. The nine planets move in orbits that are nearly circular.
2. They carry with them 97 percent of the angular momentum of the whole system, and angular momentum cannot be lightly regarded in an evolutionary plan.
3. The planets are well spaced from each other, with the sizes and masses tapering off in both directions from Jupiter.
4. The rotation of the sun, and the orbital revolutions of the nine major planets and most of the satellites and asteroids, are in the same direction (counterclockwise as seen from Polaris), which is also the direction of the axial rotation of most of the planets, if not all.
5. Because of radiation pressure, dissolution, and dismemberment through other causes, the comets are short-lived, relative to the age of the earth's crust; but their abundance and behavior enrolls them as a part of the solar family.
6. The mean density of the earth is 5.5, but of Saturn 0.7 (it would float in water!).
7. A great but faint comet of which the orbit is totally trans-Jovian varies unpredictably in brightness by large amounts.
8. Conspicuous constituents of the solar corona are very highly ionized atoms of iron, nickel, and calcium.
9. The sun's present isolation in space makes collision or near encounter with another star an improbability of high degree—say, one collision in a billion years, to be optimistic. (In very ancient time, as noted below, the chances for constructive disaster were probably much higher.)
10. The subsurface temperature and radiation pressure of the sun are exceedingly high; the sun is gaseous from surface to center and generates energy subatomically in such a manner that the present size has not appreciably changed in a billion years or more.

It would take too much space to comment on the foregoing items, or to discuss various hypotheses that have succeeded in satisfactorily explaining or harmoniously using a few of them. The most serious obstacle to a successful hypothesis is the distribution of the angular momentum; the planets have so much, the sun so little. The near-circularity of the orbits, and the violently explosive nature of high-temperature gas when the pressure is released, are probably the two next most difficult properties to handle.

We generally agree that no hypothesis of the origin of the earth is as yet satisfactory. In recording this attitude we have in mind the nebular hypothesis associated generally with the names of

Laplace, Kant, and Swedenborg; the collision hypotheses of Buffon and, much later, of Bickerton; the tidal-disruption theories of Chamberlin and Moulton, Jeans, and Jeffreys; the grazing-impact hypothesis of Jeffreys; the double-star plus collision suggestion of Russell as developed by Lyttleton; the vague nebular-filament hypothesis of Nölke, and various internal-explosion theories, such as that considered by Ross Gunn. There are variations on some of these hypotheses, and some of them have been repaired by ad hoc assumptions and subhypotheses. Eventually one of them may be patched up into scientific respectability. Among the modern critics have been Luyten, Hill, Jeffreys, and, most usefully, Russell, who has critically examined both the data and the theories.⁷

At present the general feeling seems to be that the earth probably came from a star, and that it is therefore the daughter of catastrophe. The mass is not large enough to make the precrustal existence clear or simple, but it must have been brief. Doctor Jeffreys has recently written:

I think that the most serious difficulty of all catastrophic theories, affecting both Jeans's theory and mine, and also Lyttleton's further modification, is that the newly formed planets would need to be able to control not only the velocities of thermal agitation but also those of general expansion due to the sudden relief of pressure.⁸

A RETREAT INTO CHAOS

From the foregoing summary it is clear that our hope of tracing an orderly progress in the origin and career of the earth is still deferred. An elaborate examination of the dynamical history of the various planets may be helpful in the search for an acceptable theory; and possibly the contributions from geologists and seismologists concerning the inner structure of the earth may be suggestive. There is work of useful sort to be done on asteroids, comets, and meteors; and a searching of the stars and interstellar spaces of the solar neighborhood for giant planets that act like stars, and subdwarf stars that simulate planets. With the recent discovery of a neighboring star (mass unknown) that is about a million times fainter than the sun,⁹ we may be led in the direction of thinking of Jupiter, which has a mass one-thousandth the solar mass, as an extinct subdwarf companion of the sun. That concept would turn our cosmogonical speculation more in the direction of the dynamics of double stars with unequal components than in the present direction of collisional and catastrophic phenomena.

⁷ The solar system and its origin. The Macmillan Co., New York, 1935.

⁸ Nature, vol. 153, p. 140, 1944.

⁹ Van Biesbroeck, G., Harvard Announcement Card No. 678, January 26, 1944.

Several years ago, despairing of our finding an acceptable orderly theory of the origin of the planets, I proposed an alternative that cannot be easily disproved.¹⁰ It might be called the hypothesis of the chaotic origin of the solar system. It ties in earth-birth with the genesis of stars. We should remember that the hardest problems of cosmogony would not necessarily be disposed of even if we should get a satisfactory theory of the origin of the earth. For we would ask at once concerning the origin of the sun and of galaxies, and eventually be driven back to the deeper puzzles of the origin of matter, origin of space, of time, and of origins. Planetary genesis is therefore only a decoy, leading to universal processes.

One working hypothesis of the origin of stars prescribes that they have come disruptively from an original all-encompassing mass (Lemaître's cosmic atom), perhaps through several shattering explosive stages. Other cosmogonies also require high concentrations of matter at some past time, perhaps at "the beginning of things."

On the chaos hypothesis we assume that whatever collisional or explosive event produced the sun also simultaneously produced a very large number of fragments. Much of the debris has subsequently been lost—diffused or driven off as gases, or as particles dynamically ejected. If, in this confusion, the great fragments that are now Jupiter and Saturn moved in the same direction around the gravitationally controlling primitive sun, and moved in practically the same plane, they together might in time set the tune for the surviving fragments (planets and asteroids). We must visualize a long cleaning-up process, in which bodies with highly elliptic orbits were rejected or captured, and those with other-direction motions likewise subjected to dynamical elimination. The bodies with essentially circular orbits, rightly spaced and oriented, revolving in the correct direction, are the only natural survivors of the cleaning-up and regularization.

There are, of course, difficulties even with this generous chaotic hypothesis—for instance, the present nonexistence of orbits of high inclination (except cometary). But its greatest weakness, of course, is that it represents a council of despair—it is the antithesis of "orderly procedure" at the time of the system's origin. Nevertheless the hypothesis would certainly suffice to end our search, because in the primitive star-making violences, and in the confusion of bodies, motions, and explosive processes, almost any detail can be specified. The momentum puzzle could be bypassed, and the other difficulties resolved by appeal to forces of varied and irregular fragmentation.

My suggestion¹¹ really amounts to saying that the planets and

¹⁰ Facts and fancy in cosmogony. Annual Sigma Xi address, Atlantic City, December 28, 1932.

¹¹ The Sigma Xi address was not published. Somewhat later H. N. Russell independently made a similar suggestion, and probably others have also.

satellites are as we find them and move as they do because they were born that way; and that may be the correct answer. We have some evidence that the stars may have been catastrophically born; and, if they were, how can we escape the likelihood that minor bodies also appeared at that time and came under the gravitational control of the nearby stars? Meteors, meteorites, comets, asteroids, and the small satellites are almost certainly the products of fragmentation. Why not date at least some of them, if not all, from the Crowded Days of Chaos, and not struggle to make them the regularized offspring of the orderly dynamical processes that are observed, at this late time, smoothly operating in our isolated solar system?

ON T₀ AND THE OVERCROWDING

The isolation of the sun with respect to its neighboring stars is average for this part of the Milky Way. The stars in the Pleiades, on the other hand, are relatively much closer together, and in the center of a globular star cluster, like Messier 13 in Hercules, the separation of one star from another must be less than one-hundredth our distance of 4.3 light-years from Alpha Centauri, the nearest known neighbor. Nevertheless, in these densest clusters the stars are still well separated. We see in them no evidence of frequent collisions.

Similarly, our galaxy of stars is pretty well isolated in metagalactic space. The Clouds of Magellan (much smaller galaxies than our own) are perhaps within the spherical star haze that surrounds our own galaxy; but the nearest great spirals (the Andromeda Nebula and Messier 33) are nearly a million light-years away. Nevertheless, the galaxies, large and small, in this part of the universe are perhaps 10 to 50 times as numerous per cubic megaparsec¹² as in most of the metagalaxy that is now under observation. The typical galaxies average a million or so light-years apart, and their random speeds of a few hundred miles a second are not sufficient to provide numerous collisions and encounters.

The dominant motion of the galaxies, as far as we can ascertain it, is the spectroscopically measured radial motion. Five hundred objects have been measured with the large reflecting telescopes. After V. M. Slipher's pioneer work on the speeds of these external galaxies, Milton Humason of Mount Wilson has contributed most of the observed values. With this material on motion, Hubble has derived the well-known linear relation between the red shift and distance. If we interpret the red shift in the spectra of the galaxies as the result of recession, then the linear relation is between velocity and distance. For many good reasons such an interpretation of the red shift is gen-

¹² A megaparsec is 3,260,000 light-years.

erally accepted by astronomers and physicists, although it is recognized that some as yet unknown factor may contribute to the spectral characteristics of these objects which are so distant that their radiations must spend from 1 million to 150 million years in intergalactic space.

It is well known that the expansion of the universe (recession of the external galaxies), which increases in speed with distance from the observer (wherever he is located), is consistent with the theory of relativity. The recessions are, in a sense, predicted. If and when we are able to extend our observations to more distant galaxies, it is quite probable that the relation between red shift and distance will deviate from linearity.

For the present discussion we shall look toward the past rather than the future—toward an epoch of crowding rather than toward unending dispersion. The present observed expansion is such that at a distance of 1 million light-years a galaxy recedes at the rate of about 100 miles a second; at a distance of 5 million light-years, at a rate of about 500 miles a second. One naturally asks if this expansion has been going on throughout the whole time that the earth's crust has been in evolution. There is no reason to think that the situation has been otherwise. Let us therefore see where the galaxies were when the earth was young.

We take the rate of expansion specified above (its uncertainty is small), and using the number of seconds in 2,000 million years, which we assume for calculational purposes to be the age of the crust, we calculate

$$2 \times 10^9 \times 3.2 \times 10^7 \times 10^2 \text{ miles} = \\ \text{approximately } 10^6 \text{ light-years}$$

as the distance traveled, since the crust formed, by a galaxy that is now a million light-years distant. This would indicate that such a galaxy was, at the time of the origin of the earth, in the immediate vicinity of our galaxy. Since the velocity of recession is proportional to the distance, we would find the same result for galaxies now distant 10 million and 100 million light-years. Therefore, some 2,000 million years ago all of the untold myriads of galaxies, according to this argument, were here with us, perhaps overlapping our galaxy, or at least in its close neighborhood. The congestion would be astoundingly high. Recently I have estimated, from the available metagalactic census reports, that more than 20 million galaxies are within range of our telescopes; more than 500,000 are already on the Harvard photographs. But even our greatest telescopes do not reach "all the way." A fair surmise, based on Eddington's version of a relativistic cosmogony, would make the total number of galaxies in the universe greater than 10^{11} , the number of stars greater than 10^{22} , and the mass of the universe about 10^{55} grams. The corresponding number of

atoms, since the universe apparently is still largely composed of simple hydrogen, is of the order of 10^{29} .

We have measured the velocities of a good and representative sample of galaxies; but we should not extrapolate back too confidently in our search for the zero point of time. Throughout the past the rate of expansion may not have been constant at the presently observed value. It may have been increasing with time. That assumption would lengthen the interval between now and the zero time of the expansion. But, however we try to modify the situation, within reason, we come to the conclusion that a few thousand million years ago our galaxy was in a region characterized by an exceedingly high density of galaxies, stars, and matter.

We should now point out some important, almost dramatic, coincidences. It is remarkable enough that the age of the observed expansion of the metagalaxy is of the same order as the age of the earth's crust, measured by radioactivity, and therefore of the earth itself. But this interval of a few thousand million years also measures the somewhat preliminarily determined ages of the oldest meteorites so far examined. It is also the interval through which star clusters like the Pleiades must have existed; they cannot be more than a few thousand million years old according to dynamical researches by Bok and others. And finally, this interval, according to the recent work of Chandrasekhar, is consistent with the ages of wide binary stars.

Although it has not been worked out quantitatively, there is a suggestion that in proving the existence of extended clouds of dust in our Milky Way, W. S. Adams at Mount Wilson has provided another indicator that our galaxy cannot have existed for very many thousands of millions of years.

We come to the conclusion, important in cosmogony, that about half a dozen lines of evidence point to a time some 3,000 million years ago as an epoch when something momentous happened. One could call that moment "creation," if he made his definitions carefully. He might simply call it the beginning of the epoch of the Expansion of the Universe, with its numerous consequent byproducts. Or he might more simply and safely call it T_0 , and leave to the investigators of the future both the further testing of its reality and the speculations as to its meaning.

It should promptly be put on record that all the astronomical evidence and speculation is not definitely on the side of this "short" time scale of a few thousand million years. To many of us that interval seems to cramp sidereal processes too severely. I have in mind the sequence of types of galaxies; some indications of the ages of the individual stars; the evolution of globular star clusters. It may be that these phenomena can be so interpreted that the short time scale is sufficient for everything we observe and reason about. But we

could well be cautious and say only that the evidence of the moment is fairly strong in favor of the view that the planets, the meteorites, the galaxies, the double stars, possibly the clusters of galaxies, and certainly the expansion of the galaxies in the observable part of the metagalaxy, all date back to T_0 . Now, a time interval of only 300 million years since T_0 certainly would not be long enough; and 30,000 million would be too much. The geometrical mean, 3×10^9 years, is a convenient number to remember as our current approximation.

It is not necessary, of course, to go along with Lemaitre's exploratory suggestion and put all the matter of all the galaxies into one original cosmic atom, the explosion of which produced the phenomena that we now observe. But it is consistent with our various observations to accept the former existence of a very highly compressed material universe, in which stellar collisions might be numerous, fragmentation a common occurrence, and where the prevailing general confusion of matter and motions would suit requirements for an initial chaotic phase in the development of the solar system.

Certainly the time T_0 is a zero point of significance to students of galaxies, clusters, meteors, and the origin of the earth. If the cosmic violence at that time was sufficiently high-temperated, it may be that the origin of the highly penetrating cosmic radiation should also be dated from T_0 . Some years ago De Sitter suggested that the stars themselves may antedate the expansion. And, of course, there might have been a long prestellar state of the universe before the shock of 3×10^9 years ago started the currently existing processes.

It may require active research throughout one or two geological periods in order to settle finally the questions we have raised.

THE FUTURE OF THE METAGALAXY

In the concluding section of this random discussion of certain points in cosmogony, we get completely disconnected from the earth and geology. The significant constituents of the metagalaxy in our existing cosmogonies are space-time, radiation, the unit galaxies, and interstellar dust and gas. We have been content, in the solar system and even throughout our own galaxy, with gravitation as a dominating force in the moving of stellar bodies. Radiation pressure is in general effective only for particles of a diameter comparable with the wave length of the radiation. It does not push stars or galaxies around. But of late years, as a byproduct of relativistic cosmogony, we have come to the concept of a new force—cosmic repulsion. It might be called negative gravitation. Its effect can be loosely described as the tendency of material bodies to scatter from each other when the mean density of matter in space sinks below a certain exceedingly small value.

It is the cosmic repulsion that is effective in the recession of the

galaxies and the expansion of the universe. The average density of matter throughout our planetary system and even throughout our galaxy is so high that the dispersive tendency is overcome by the great gravitational forces involved. Even in a cluster of galaxies—like the one in our vicinity which includes our galaxy, the Andromeda Nebula and its companions, the Magellanic Clouds, and half a dozen others—gravitation still controls the situation, and our cluster of galaxies is not dissolving under cosmic repulsion—at least not with marked rapidity. The cohesion that maintains our cluster apparently operates in a number of other close associations of galaxies which have come into our records. The mean density in them is high enough for gravitational control. But throughout metagalactic space in general the mean density is perhaps but one-hundredth of the value within the cluster of galaxies. The density is, in fact, about 10^{-29} grams per cubic centimeter and too low for gravitation any longer to maintain the situation. The expansion that has set in under the repulsive force will still further lower the mean density, and it therefore now appears that we (the metagalaxy) are doomed to infinite dissipation.

At the same time, through the operation of the laws of thermodynamics, the heat of the stars is going out into the coldness of space. The universe is steadily approaching the heat-death—a coldness near absolute zero in an empty world.

Such destinies define the future of the metagalaxy only if the processes are forever one-directional. Perhaps they are not. Even now we cannot say that the reverse building-up processes are not going on in some parts of the universe. We see less than 1 percent of it. There is, however, no substantial evidence or argument for the cyclic restoration of heat and density. And some cosmogonists are bold enough to abstain from wishful thinking.

A further section of this paper could be written to review the situation with regard to interstellar dust and its possible role in the forming of stars and in the development of galaxies. Also we might present the preliminary hypotheses that deal with the evolutionary passage of galaxies along the continuous sequence of forms that includes systems that are globular, oblate, spiral, and irregular; and discuss the nature and the formation of spiral arms. The genetics of star clusters is an allied study of basic significance. But all these galaxy-sized problems are so remote from those dealing with the crust of the earth and its genesis that we can scarcely justify their discussion in a collection of geological papers. We close this astronomical contribution with the statement that the planet earth has, after all, a most perplexing and exciting role in the story of cosmogony.

ATOMIC POWER IN THE LABORATORY AND IN THE STARS¹

By ROBERT S. RICHARDSON

Mount Wilson Observatory

When on August 6, 1945, President Truman announced the destruction of the Japanese army base at Hiroshima, he did so in words of singular interest to astronomers.

"It is an atomic bomb. It is a harnessing of the basic power of the Universe. The force from which the sun draws its power has been loosed against those who brought war to the Far East."

Several conversations heard shortly afterward indicated that many took the President's words literally, and assumed that radiant energy from the sun had in some mysterious way been concentrated in bomb containers for use against the Nipponese. Presumably people have become so accustomed to startling technological developments during the last 3 years, that they are willing to believe practically anything. A few remarks clarifying the situation may be of timely interest.

The most obvious feature about the stars is by far the hardest to explain—the fact that they shine! In other words, what is the "force from which the sun draws its power"? In their search for an answer, astronomers have eagerly seized upon each discovery in physics that might possibly help them with their own problems. Thus any summary of the various answers given to this question becomes essentially an account of the growth in knowledge of the fine structure of matter. In this article it is proposed to examine these theories, not so much with respect to their intrinsic merit, but more for the gradual modification they have undergone as the result of physical discovery.

Doubtless men have always propounded theories to explain the source of the sun's heat. The first *rational* theories were not advanced until about a century ago, soon after the principle of the conservation of energy was clearly recognized. Previously they had been little more than mere fanciful speculation. As for example, Sir William Herschel's assumption that the photosphere arises from the decompo-

¹ Reprinted by permission from Publications of the Astronomical Society of the Pacific, vol. 57, No. 338, October 1945.

sition of the solar atmosphere into clouds with the emission of light and heat; or worse still, the suggestion by Sir John Herschel that the vital energies of monstrous creatures—the willow leaves of Nasmyth—are the true source of luminosity! Two famous theories based upon the mechanical equivalence of heat originated about the middle of the nineteenth century. Although discarded long ago, they still are accorded respectful mention because they contain at least some basis of sound physical reasoning.

The first theory of the meteoritic origin of the sun's heat was announced by J. Robert Mayer² in 1848. Mayer claimed to have been the first to enunciate the principle of the conservation of energy, but seems to have discussed it in such obscure terms that he never received clear title to the distinction. There is no question, however, that he anticipated Helmholtz by 2 years in this respect.

Mayer pointed out that space is known to be filled with innumerable small bodies many of which must be drawn into the sun with a speed approaching the parabolic velocity of 380 miles per second. As they plunge into the sun, their energy of motion would be converted into heat. He calculated that a total mass equal to $\frac{1}{74}$ of the earth's mass striking the sun annually would be sufficient to maintain its observed output of energy. At first glance this appears quite reasonable, and for a few years Mayer's theory enjoyed considerable success. Closer examination, however, revealed that on this basis the earth should receive from meteoritic bombardment millions of times more heat than could possibly be admitted, so that the theory soon became of historical interest only.

A theory ascribing the source of the sun's heat to friction but in a wholly different way was first described by Helmholtz³ in a popular lecture delivered on February 7, 1854. He showed that as the sun loses heat by radiation it must contract, and this contraction is equivalent to the fall of particles by various amounts depending upon their distance from the center of the sun. Making the most unfavorable assumptions, Helmholtz found that a shrinkage of 250 feet per year would be enough to supply the sun's annual output of energy, an amount too small to be detected for 10,000 years.

One of the necessary conditions which any theory of solar radiation must fulfill is that the temperature of the earth has not sensibly diminished in historical times. As evidence of this condition, Helmholtz cited the cultivation of grapes and olives, plants extremely sensitive to temperature changes, over the same regions that prevailed in the days of Homer. Against this evidence it was argued that formerly the German knights had made their own wine and drunk it, but the

² Republished in *Philos. Mag.*, vol. 25, p. 241, 1863.

³ *Philos. Mag.*, vol. 11, p. 489, 1856.

quality of the grape had changed so much that this was no longer possible. To this Helmholtz replied that it was more likely that the throats of the drinkers had changed rather than the climate of their country.

Astronomers became so convinced of the truth of the contraction theory that they arbitrarily told geologists that the maximum age of the earth was 25 million years, and to adjust their evolutionary scale accordingly. This the geologists flatly refused to do, as they had reasons for believing that the age of the earth was more than 100 million years.

Toward the close of the century, the discovery of radioactivity by Becquerel and the isolation of radium by the Curies led to the uneasy suspicion that friction might not be the sole source of solar radiation. In 1899, T. C. Chamberlain,⁴ a geologist, dared to challenge the contraction theory as well as boldly to predict, with startling insight, sources of subatomic energy. "What the internal constitution of the atoms be is yet open to question," he wrote. "It is not improbable that they are complex organizations, and the seats of enormous energies. . . . Are we quite sure we have yet probed the bottom of the sources of energy and are able to measure even roughly its sum total?"

With the reluctant abandonment of the contraction theory there followed a long interlude during which astronomers could give no definite answer to the question, "What is the force from which the sun draws its power?" They could watch radium release enough energy every hour to melt more than its own weight of ice, knowing that it could continue to do so for another 1,000 years. Application to the sun, however, was little more than a hopeful possibility. No radioactive substances had been identified in the solar atmosphere, and there was small prospect of detecting spectral lines of such heavy elements. Besides, nobody had the faintest idea whence radium derived its energy. Then in 1905, Einstein⁵ published a paper of less than 500 words which changed the whole situation and has continued to exert an ever-increasing influence on modern physics. From considerations based upon the electrodynamics of moving bodies, he showed that if a body gives off energy, L , in the form of radiation, its mass diminishes by L/V^2 , where V is the velocity of light.⁶ From this he concluded, "it is not impossible that with bodies whose energy-content is variable to a high degree (e. g., with radium salts) the theory may be put to a successful test."

There appeared to be two ways in which mass might be converted into energy. The more radical involved the total annihilation of matter. The case generally envisaged was a head-on collision between

⁴ Science, vols. 9 and 10, 1899.

⁵ Ann. Physik, vol. 18, p. 639, 1905.

⁶ This is Einstein's original notation.

an electron and a proton in which both vanish, only to reappear as a radiation of frequency 2.3×10^{23} . There could be no doubt that such a process occurring within the deep interior of stars would certainly provide a potent source of energy. Chief drawback of the annihilation process was the total absence of observational evidence to support it. A less energetic but more likely reaction was the formation of heavier elements from hydrogen. If, as was then supposed, a helium nucleus consisted of four protons and two electrons, its atomic weight should be four times that of hydrogen, or $4 \times 1.008 = 4.032$.⁷ On the contrary, accurate measurements made by Aston in 1920 with the mass spectrograph revealed that the atomic weight of helium is 4.002. Thus 0.030 mass units had presumably been liberated as energy in the atom-building process.

While the transmutation of hydrogen seemed fairly plausible and was capable of furnishing the minimum amount of energy that the cosmologists demanded for their various hypotheses, yet Eddington, summarizing the state of affairs in 1926, found the outlook anything but bright. Attempts to formulate a theory of stellar evolution based upon the transmutation of hydrogen were invariably strained. Every argument led to a deadlock. "Unfortunately, the facts as yet do not fall into satisfactory order," he regretfully admitted, "and we are still groping for a clue."⁸

For another 10 years astronomers continued to grope for the essential clue before it gradually became apparent. In 1919, Rutherford, by bombarding nitrogen with alpha particles, had obtained oxygen of atomic weight 17—the first case of the artificial transmutation of the elements. A whole new field of research was opened, which atomic physicists immediately invaded with great exultation. Exciting discoveries and epoch-making developments followed with breath-taking speed: the positron, the neutron, artificial radioactivity, the cyclotron, together with the production of a host of strange particles by nuclear disintegration unknown a few years before. And since large quantities of energy were released in many of these disintegration experiments, astronomers began to eye them with covetous eyes.

By 1939 both our experimental and theoretical knowledge had progressed to such an extent that it was possible to decide which reactions might be responsible for the production of energy in stars similar to the sun.⁹ First, all nuclear reactions that might conceivably contribute to generating energy in the sun were written down. Then

⁷ Now, the helium nucleus is believed composed of two protons of weight 2×1.00753 and two neutrons of weight 2×1.00893 , so that the weight of the separate parts should be 4.0302. The latest value for the weight of the helium nucleus is 4.00280, giving a difference of 0.03022.

⁸ Internal Constitution of the Stars, p. 297.

⁹ H. A. Bethe, *Phys. Rev.*, vol. 55, p. 434, 1939.

opposite each reaction was written the quantity of energy liberated, the rate at which the reaction would proceed at the temperature calculated for the center of the sun, 20 million degrees, and finally, the "mean life" or average time required for the reaction to take place.

Inspection of the table revealed that only a very few reactions would provide energy at the rate emitted by the sun. At 20 million degrees some reactions would occur so rapidly that the sun would explode, while others were far too sluggish. In fact, it was pretty obvious that observations could be satisfied only by a particular series of reactions in which hydrogen combining with carbon and nitrogen is transformed into helium with the liberation of energy. The unique feature about the series is its cyclical character, neither carbon nor nitrogen being consumed but serving as true catalysts for the combination of four protons and two electrons into an alpha particle. Thus 85 years after the origin of the contraction theory, astronomers finally found in the carbon-nitrogen cycle a reasonably satisfactory answer to the question, "What is the force from which the sun draws its power?"

It must not be supposed that astronomers now sit back complacently and regard the matter as closed. Although the carbon-nitrogen cycle accounts very well for the production of energy in stars like the sun, it has not been so successful when applied either to very luminous white stars or cool red giants. Thus γ Cygni, which is 32,000 times as bright as the sun, must be converting hydrogen into helium so fast that it can hardly have been shining at its present rate for more than 35 million years, and probably has only enough hydrogen left to continue for another 170 million years. If the present age of the universe is 2,000 million years, then stars like γ Cygni are truly "brief candles" blazing for a few cosmic minutes only. At the other end of the sequence are stars like Capella which have a central temperature calculated to be about 6 million degrees, so low that the carbon-nitrogen cycle would fail to operate effectively. In order to explain the production of energy in the red giants we are forced to rely on proton reactions with deuterium, lithium, and beryllium, which occur at relatively low temperatures. But it is hard to see how these light elements were built up in the red giants in the first place.

A question which naturally arises at this time is "Why was not subatomic energy used as a source of power in the '30's?" It would seem that if nuclear reactions produce so much heat, and if physicists knew how to produce them, then why not harness them for industrial use immediately? For example, the energy liberated from the transformation of a single pound of lithium and hydrogen in the proper proportions would release as much heat as can be obtained from the combustion of 3,150 tons of coal.

The answer is that these reactions can be produced in the laboratory only on an infinitesimal scale by the expenditure of far more energy than they release. The nuclear reactions observed before 1939 are fundamentally impractical as commercial sources of power because they are not self-propagating. A fire once started will continue to burn as long as fuel is available. But in the proton-lithium reaction just mentioned, the few alpha particles formed do not lead to other reactions with additional release of energy. Subatomic energy, if it is to be harnessed efficiently, must start a chain reaction that will proceed to release energy of its own accord.

Two decades after Rutherford launched physicists upon an orgy of atom splitting, Hahn and Strassmann¹⁰ reported a new type of nuclear reaction which has become of transcendental importance. Following up experiments by Fermi, Irene Curie, and others, they had bombarded uranium with neutrons and obtained some radioactive substances whose chemical properties resembled barium. This led them to think that these new substances were probably isotopes of radium, which is chemically similar to barium. Further analysis, however, failed to distinguish these products from barium, and at last they were forced to conclude that the new substances actually were isotopes of barium. All previous experiments on nuclear disintegration had succeeded only in transforming the reacting elements into others of slightly different atomic weight, such as nitrogen to oxygen, beryllium to carbon, etc. But in this experiment, neutron bombardment of uranium of atomic number 92 at the end of the periodic table had resulted in the appearance of an element of atomic number 56 near the middle of the table.

The experimental result also conflicted with theoretical ideas concerning the nucleus. Previously it had been supposed that the rapid emission of large numbers of charged particles from the nucleus was precluded by the "Coulomb barrier," or potential field of force surrounding the nucleus. This was pictured as a steep, craterlike barricade which prevented exterior particles from reaching the nucleus, as well as preventing the nuclear particles from escaping. Using a new nuclear model proposed by Bohr¹¹ 2 years before, Lise Meitner and O. R. Frisch¹² showed that a rather simple explanation was possible. In Bohr's theory, the particles composing the nucleus of a heavy atom can be considered as behaving somewhat like the molecules in a drop of water. Collectively, the molecules cling tightly together, but occasionally one near the surface, through a series of favorable collisions, will gain sufficient speed to fly off or "evaporate." In the nuclear case,

¹⁰ *Naturwiss.*, vol. 26, p. 756, 1938.

¹¹ *Nature*, vol. 137, pp. 344, 351, 1936.

¹² *Ibid.*, vol. 143, p. 239, 1939.

this corresponds to the escape of an alpha particle or electron from radioactive elements. If a drop of water is violently disturbed it may break into several parts. Similarly, if the nucleus receives a powerful shock, as when struck by a neutron, it may divide in two, the process which has since become known as "nuclear fission."

Meitner and Frisch also called attention to the tremendous energy released by the fission of uranium. When uranium, the heaviest element of all, is split into two elements of roughly half its weight, there is an excess of mass which is converted into energy of an amount given by Einstein's mass-energy relation.

The energy released by fission of one uranium atom is in engineering units 0.000320 ergs, which means that to produce one horsepower we would have to split 23,300 billion uranium atoms per second. Let us try to visualize these figures in terms of familiar things. To toast a slice of bread in an electric toaster takes about 15,500 calories. Assuming 100-percent efficiency in the atom-splitting process, the same energy could be obtained from thirty-billionths of an ounce of uranium. Or for an entirely different example, a 100-ton locomotive could run from New York to San Francisco on 0.02 ounce of uranium metal.

Most important of all, uranium fission releases neutrons which are more effective in splitting nuclei than protons or alpha particles would be, since, having no charge, they are not repelled as they approach the positively charged nucleus. In the ideal case, the reaction would spread with increasing rapidity and if uncontrolled would lead to an explosion of tremendous violence. Even if the chain spreads much more slowly than in the ideal case the release of energy would still be of unprecedented violence, providing that the multiplying factor were always greater than unity, and was "compounded" very rapidly. According to reports, this entire detonation problem was and still is one of the most difficult encountered in designing a highly efficient atomic bomb.

Further work indicated that the uranium involved in the fission reaction is a rare isotope of atomic weight 235, which comprises only 0.7 percent ($\frac{1}{141}$ part) of the metal occurring in nature, most of which is of atomic weight 238.

In the light of recent events, it is interesting to look back at some of the comments on uranium fission made about 1940. One writer,¹³ after mentioning several points in connection with the new process, remarked: "These five points are the fancy which may or may not come true within our time. There are others, like the uranium bomb, which go beyond fancy into the fantastic." Again, E. O. Lawrence¹⁴ spoke of the

¹³ Robert D. Potter, *Sci. Month.*, vol. 50, p. 571, 1940.

¹⁴ From an address given at Stanford University in June 1941; reprinted in *Ann. Rep. Smithsonian Inst.*, 1941, p. 163.

possibility of a chain reaction that has excited the interest in uranium as a practical source of atomic energy * * *. It is perhaps sufficient to say that there is some evidence now that, if U^{235} could be separated in quantity from the natural mixture of isotopes, a chain reaction could, indeed, be produced. But herein lies the catch, for there is no practical large-scale way in sight of separating the isotopes of the heavy elements, and certainly it is doubtful if a way will be found. But I should not want to indicate that the uranium matter is a disappointment * * *. Success in this direction may await the development of a new instrument or technique just as the airplane depended upon the gas engine.

H. E. White¹⁵ faced the future with more confidence.

Should uranium atoms of atomic weight 235 be responsible for the observations just described, it seems reasonable to suspect that a small piece of uranium metal, composed entirely of these atoms alone, should act like a bomb and explode with far greater violence than any known explosive. Here then may be the source of energy that will make the rocket ship a reality.

Distinctly disquieting is the note struck by a series of papers published in *Nature* and the *Physical Review* on the products of uranium fission produced by neutron bombardment by several Japanese workers at the Nuclear Research Laboratory in Tokyo. Using one of the largest cyclotrons in the world, on May 3, 1940, they were able to announce production of a radioactive element of atomic number 93. This is the element later named neptunium which, with plutonium of atomic number 94, played such an important part in the development of the atomic bomb. There can be no doubt that the Japanese were thoroughly alert to all the possibilities of the reaction.

Can uranium fission help in the problem of stellar energy production? Already Saha¹⁶ has suggested that the highly ionized atoms of iron, nickel, and calcium identified by Edlén as the source of the coronal lines have been produced through some process akin to uranium fission. Perhaps it is too early as yet to attempt to apply this new knowledge to specific astrophysical problems, but its eventual importance cannot be doubted.

One of the most embarrassing questions which astronomers are frequently called upon to answer is, "What use is astronomy? Why bother to look at a star you can see only through a 100-inch telescope?"

The atomic bomb should provide an eternal answer to such queries. So-called "practical" men would certainly have found little to interest them in the experiments and theories which atomic physicists found so fascinating prior to about 1940. It is true that the cyclotron had valuable applications in therapeutics. But on the surface, much of the work would have seemed as useless as the discovery of a white dwarf star or the identification of molecules in interstellar space. Yet

¹⁵ *Classical and Modern Physics*, p. 615, 1940.

¹⁶ *Observatory*, vol. 66, p. 18, 1945.

both physicist and astronomer were concerned with the investigation of the fine structure of matter, the physicist in his laboratory on the earth, the astronomer in his laboratory of the sky. And investigation of the fine structure of matter was directly responsible for the atomic bomb.

The essential identity of the two lines of research is tacitly recognized in President Truman's statement, "The force from which the sun draws its power has been loosed against those who brought war to the Far East."

ATOMIC ENERGY AS A HUMAN ASSET¹

By ARTHUR H. COMPTON

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It is with high appreciation combined with a deep sense of humility that I accept tonight the Franklin Medal of the American Philosophical Society. Coming as it does from my colleagues whose respect is to me a matter of the greatest value, you must know that this honor is most highly appreciated. Yet the inscription on the Franklin Medal reminds one of virtues which, though called for by the critical times through which we are passing, are scarcely to be found. Benjamin Franklin himself combined the qualities of scientist with those of statesman in unusual degree. Now, in the age of atomic energy, such a combination is needed by the world as never before.

It is with diffidence that we who have been working on the technical aspects of atomic energy present before a group of experts such as are here tonight our amateur thoughts with regard to its human implications. Yet action is needed, and only by boldly presenting our thoughts for discussion can a reasonable basis for such action be reached.

The ability to release atomic energy gives mankind great new powers. These powers can be used for good or ill. The first use of atomic energy was as a bomb whose explosion stopped short a tragic war with the probable net saving of some millions of lives. Its terrific military destructiveness has made it necessary for us to consider afresh how we may avoid future wars. The dramatic demonstration of its explosive power has, however, drawn attention away from the significance of atomic energy to our industry, our habits of life, and our culture. It is in such peacetime consequences that atomic energy will eventually mean most to man.

The atomic age has started as a period of keenest rivalry. The rivalry is between nations and social systems. The prize to be won is prosperity and world leadership. It can include peace and security. If only we agree to place war beyond the power of nations, the race is sure to make life of greater value. Such is the prospect of a world

¹ Franklin Medal Lecture, read November 16, 1945, in the Symposium on Atomic Energy and its Implications. Reprinted by permission from Proceedings of the American Philosophical Society, vol. 90, No. 1, January 1946.

strengthened by unlimited power from atomic fission and forced away from war by the examples of Hiroshima and Nagasaki.

I want tonight to consider the human consequences of the release of atomic energy in three major directions. First is its effect on war and the world's political structure. Second is its application to the practical tasks of peace. Third is its effect in changing the form of our social life and customs.

1. HOW SHALL WE PREVENT ANOTHER WAR?

World government has become inevitable. The choice before us is whether this government will be agreed upon or whether we shall elect to fight a catastrophic third world war to determine who shall be master. Unity by agreement will bring greater life. Unity forced by another war will bring death to many millions and disaster to all mankind.

The primary function of this world government must be to prevent international war. With regard to its economic and cultural life the world has during the past century been developing into a unit in which the welfare of each person depends intimately upon that of the rest of humanity. We have indeed become "members one of another." Such development has not however resulted in political world unity. The great destructiveness of an atomic war, even to the victor, makes it necessary now for self-preservation to insure peace. In a quarrelsome world the only means of insuring peace is, however, for the nations to set up an international police force which monopolizes the power to wage war.

Now for the first time, however, it becomes feasible for a central authority to enforce peace throughout the world. Before World War II many parts of the earth were difficult of access by a world police. If not a Maginot Line, at least a strong fighting front could keep out a policing army. During the time required to bring this policing army to the scene the defense of the recalcitrant group could be strengthened.

Today this is changed. Fast airplanes, long-range rockets, and atomic bombs have now solved the technical problem of bringing to bear on any area at any time whatever destructive force may be required to quell resistance. A central authority having virtual monopoly of these major means of warfare can now be equipped to enforce international peace.

The fact is that the United States now has in its possession a sufficient monopoly of the weapons needed for such policing that it might be able to act in this capacity of world police. That we do not set ourselves up as the world governors is simply because we do not want the job. We feel that world control is the world's business, not ours. We know that, if we should use armed force to prevent other nations from fighting when our own interests were not directly

threatened, we should be considered meddlers and should gain only the fear and hate of other nations. We should prefer to withhold our fighting power unless our own safety is directly threatened, and confine our policing activity to our own reasonable share in keeping order within nations that are not now able to look after their own interests or that may become dangerous to us if not kept under control.

Nevertheless, looking ahead it is clear that no mere strengthening of our own might can keep us safe. Our safety cannot be kept secure by our own military development without international control of the new weapons. Whatever our strength, others also can arm so as to inflict upon us disastrous damage if war should come. What is needed is an agreement which will make our safety much surer than could result from our own armed might and which will at the same time provide for elimination of international wars elsewhere throughout the world. It is such an agreement that we should seek, sincerely, with determination, and with faith that it can be attained with reasonable promptness. The important step that has just been made in this direction by the President of the United States and the Prime Ministers of Great Britain and Canada should be welcomed by the entire world.

I am not much concerned with the precise answer to the question of how long it would require before other nations could be prepared to challenge us with atomic weapons. I know they will not do so for the next 5 years. After 25 years, unless some mutual agreement prevents their development, such countries as Britain, Russia, and France could arm themselves with weapons similar to ours if they should want to spend the necessary effort. The time required would not be greatly affected by whether we hold to our own secrets or not. It is in any case only a small part of the lifetime of our Nation that would elapse before we should be faced with the awful possibility of an atomic war.

As has been seen by the heads of our governments, now is the time when international agreements can best be made to prevent such a catastrophe. Other nations have not yet developed a pride in their atomic might which could give them dreams of world mastery. Our own effort has paid for itself many times over by stopping the course of World War II. All nations are now laying plans for the post-war years, and it will be much easier to shape these plans now on the basis of world government than to stop the wild development of a renegade nation by imposing emergency military controls after it is set in its course.

It may be worth reviewing just what we mean when we refer to the great destructiveness of war in the age of atoms. If the future demands it, science sees no reason to doubt that atomic weapons can be made that are related to the present atomic bomb much as the block

buster is to the blunderbuss. Yet even the present atomic bomb is a highly effective weapon. If one bomb will devastate four square miles and damage a hundred square miles, how many bombs are needed to destroy all of a nation's concentrations of fighting and industrial facilities above ground? Will it be 100, 1,000, or 10,000? That is a question for the military to answer. It has been demonstrated that whatever bombs are required can be produced and delivered to their targets.

Let us try to imagine what may be expected to happen if a war between two major powers should break out in 1970. We may assume that by this time both sides will have such weapons in whatever amount they consider necessary and of greater destructiveness and variety than those now possessed by the United States. Because of the enormous advantage of surprise, Pearl Harbor tactics will be employed. Jet-propelled planes or rockets with atomic warheads will be sent without warning at each of several hundred of the enemy's major production centers. No city of over 100,000 population will remain as an effective operating center after the first hour of the war. At least 10 percent of the attacked nation's population will be wiped out in the initial blow. If this nation elects to fight back, rockets and planes from hidden installations will carry the reply. The attacker in this case can expect no mercy. Though his citizens may have immediately moved underground, his great cities as well as his surface production plants will be annihilated. The fighting will continue until one side chooses to surrender or is unable to resist its opponent's army of occupation.

If the United States should be party to such a war, we should expect Philadelphia, with such neighboring cities as Reading and Wilmington, to follow Hiroshima and Nagasaki into oblivion. With the destruction of these cities we should expect about one out of every four of their inhabitants to be killed. If our Nation should eventually win, what would we have gained? Perhaps the control of the world. But of what value would this be with our civilization gone and our population decimated?

No feasible means of preventing the bombs from striking their targets has yet appeared on the horizon. Only two countermeasures have so far been proposed. The first is to disperse our cities, preferably into hilly regions, so that more bombs will be required to destroy them. The second is to place all military installations and essential industries underground and provide emergency underground shelters for all the population. Clearly such measures will seriously interfere with our normal life. So indeed was it inconvenient in the middle ages to live in a castle on a hilltop; but safety in a world of robbers

demanded such a life. Similarly now, until positive assurance can be obtained of security through an international military force, we have no alternative but to prepare such shelters and scatter our population. Death is worse than inconvenience.

We must keep in mind that, when all are armed with atomic weapons, no superiority of one nation can free it from danger of great damage by another. One man may own a .22-target pistol and another a high-power hunting rifle. But neither is insurance against murder by the other. The insurance is to take away both guns, or the fear of punishment by the police, or most surely of all the development of a social conscience for which murder becomes unthinkable.

Is there then any procedure which can free us from the threat of annihilation? I believe there is. It makes, however, the hard demands of sacrifice of national sovereignty and of faith in other peoples that will give them a share in the responsibility for our own security.

In the statement issued yesterday by the heads of the governments of Great Britain, Canada, and the United States plans are laid looking toward "entirely eliminating the use of atomic energy for destructive purposes and promoting its widest use for industrial and humanitarian purposes." They "emphasize that the responsibility for devising means to insure that the new discoveries shall be used for the benefit of mankind, instead of as a means of destruction, rests, not on our nations alone, but upon the whole civilized world."

Let us suppose that the United States, Russia, and Britain agree to transfer their own total power to wage international war to a joint Military Commission. It will be better to include France and China as the other permanent members of the Security Council so that the Military Commission can function within the framework of the United Nations Organization. This Commission will have placed under its orders the united armies, navies, and war weapons of the member nations. Its charter will give the Military Commission the responsibility for stopping any armed conflict between nations that may arise, including wars in which the member nations are themselves participants. This responsibility can be carried out since the major nations will have contributed to the Commission all of their own fighting strength except that needed for their internal policing. To be effective it seems obvious that the actions of the Military Commission cannot be subject to the veto power of any single nation but must be controlled by the joint action of some such group as the Security Council. For concreteness we may suggest further that this Commission have its seat in Canada, with its headquarters at

either Ottawa or Vancouver. Canada will accordingly be the home ground of the combined armies, the home waters of the combined navies, and in its vast territories will be dispersed the atomic weapons of the member nations ready for use in case of emergency.

As thus envisaged, the military strength of the Commission would be so great as to make hopeless the effort of any individual nation or group of nations to challenge its power. At first all of the strength in atomic weapons would be contributed by the United States. The other member nations would, however, contribute armies and planes and guns according to their proportionate share.

When the agreement is reached to the satisfaction of the member nations, the "know-how" for producing atomic weapons would be passed on to the Commission which these nations entrust with their united military power. From then on there would be no reason why atomic bombs should be made by any other group, here or in any other country. Nor is there any reason why until such an agreement is reached the technical secrets of atomic weapons should be released from the countries that now have them.

The far-reaching agreement here suggested is perhaps one that cannot be attained at one step. Time will be required to make the needed readjustments of our thinking. But the terrible threat of atomic war which Mr. Oppenheimer described so graphically this morning is upon us, and makes it necessary for us to make these readjustments before time runs out.

In the exploitation of the peacetime uses of atomic energy each nation will need to give suitable assurance to the others that its own control of its atomic industry is such as to prevent the malevolent development of weapons by any group within its borders. It is essential that such assurance include provision for the inspection to any extent that may be necessary by representatives of the international Commission.

We are thus proposing that international wars be outlawed and that responsibility for preventing wars be placed in an international Military Commission that will act under the direction of the Security Council of the United Nations Organization. This Military Commission, with its headquarters perhaps in Canada, will monopolize the armed forces of the nations that enter the agreement, except those needed for internal policing. Under its supervision atomic weapons will be produced solely for its own use. The member nations will undertake to prevent the illicit production of fissionable materials within their own boundaries, and this will be supported by permitting complete inspection of their activities by agents of the Military Commission.

If the nations follow such a procedure with courage and determination it would seem possible to insure the banishment of international wars. It will then be possible to develop with assurance the peaceful fruits of atomic energy.

Two alternatives have been suggested to this idea of preserving our safety through an armed international Commission. One is atomic disarmament. The other is maintaining our own strength on a conclusively higher level than can be attained by any combination of other nations.

I am convinced that atomic disarmament would be a fatal mistake. The proposal we have been discussing calls for the resignation by every individual nation of the right to make and possess atomic weapons; but it makes this outlawing effective by placing atomic weapons at the disposal of the United Nations Security Council. An agreement to stop producing atomic bombs would only make it possible for some ambitious nation to develop them with the hope of gaining the mastery of the world, and our destruction would be the result.

For a number of years I believe we could as a nation maintain military strength greater than any group that might oppose us. Such a policy would however tend to unite the world against us, which would in the long run be disastrous. It is, furthermore, doubtful whether over some peaceful decades our nation would continue support of our armed forces adequate to maintain a high level of superiority. We should then become vulnerable to the nation with the long-harbored grudge or the newly developed commercial rivalry.

The answer is rather to outlaw war itself. And this can be done by a strong world "police" which has at its disposal more powerful weapons than any recalcitrant nation can hope to acquire.

It is clear, however, that while working for such an agreement for a united international armed force we, as well as other nations, cannot avoid the policy of maintaining our own armed might at a level that will make attack by a potential enemy unprofitable. When our efforts for agreement are successful, our weapons and an appropriate share of our Army will be turned over to the Commission. For the time being, only we are able to produce such weapons, and it is our task to see that they are made available for this world "police." Thus the Commission will start with the strength necessary to fulfill its responsibilities. If by some mischance the attempts at an agreement should fail, our strength will be doubly needed to discourage attack from any potential enemy.

There is thus real hope that another atomic bomb may never be used in war, and, thanks in part to atomic weapons, that international war itself may already be obsolete.

2. THE PEACETIME IMPLICATIONS OF THE RELEASE OF ATOMIC ENERGY

Enough regarding the destructive uses of atomic energy. Of much more interest is its use as man's willing servant. In the long run it can hardly be questioned that the peaceful applications of atomic energy will be those that will most profoundly affect our lives. What these important applications will be is, however, as difficult to predict as it would have been a century ago, just after Faraday laid the scientific basis for electrical engineering, to tell the future meaning of electricity. At this moment the obviously great field open to atomic energy is that of production of useful heat and power. We also see important though limited medical and industrial applications of radioactive materials, artificially produced by atomic chain reactions. Perhaps more significant than either are the new vistas that will be opened up by scientific experiments that make use of the byproducts of atomic fission.

Such had indeed been the case with such discoveries as X-ray. Fifty years ago it was evident that X-rays were useful for "seeing" through objects, such as the human body, which are opaque to ordinary light. It could not be predicted that X-rays would become a powerful weapon in the fight against cancer, or that researches made by X-rays would reveal the electron and with it give us the radio and a host of electronic devices.

Such unforeseen developments are the result of every great discovery of science. It will nevertheless be worth noting some of the definite practical applications of atomic energy that we can now see clearly before us:

At present, controlled atomic power in the form of heat is in continuous production in large quantities at several plants, especially those at Oak Ridge, Tenn., and at Hanford, Wash. The heat from these plants is a byproduct, and is carried away in the one case by air and in the other by a stream of water. The useful product is neutrons which are used in the plant as a means of transmuting certain chemical elements to others of specially useful characteristics. Of these transmutation processes the most important one is that of uranium into plutonium. Previous to the fission chain reaction the most abundant source of neutrons was the cyclotron which operates on electric power. Per kilowatt of energy used, the fission chain reaction gives some 10,000 times as many neutrons as a cyclotron, and it is not difficult to make a fission chain reaction plant that delivers 100 times as much power as is used by a cyclotron. This means that right now we are using large amounts of atomic power many times more efficiently for the particular process of producing neutrons than the best electrical machine that we have been able to devise.

Looking to the future, we may expect the use of neutrons as a means

of producing new elements by transmutation to become of increasing importance. Plutonium is a concentrated source of available energy and will be a valuable material for peaceful purposes as well as for building weapons.

Other artificial radioactive elements, especially radioactive ones, will also find use in medicine, in industry, and in many branches of science. It is yet too early to see clearly how important these uses may become.

We have not yet built an atomic power plant that is generating electrical power. This is merely because we have been engaged in winning a war and there has been no serious shortage of electric power. If there were sufficient demand for a demonstration, a reasonably efficient plant using super-heated steam for driving a turbine could be put into operation within a year. Before, however, such plants can be made economical competitors with existing practice, a number of years' development will be required.

While there are several other possibilities, the most obvious method of producing power from atomic fission is to heat a cooling agent such as air or steam or liquid metal in the chain reactor unit and pass this heated coolant through a heat exchanger which heats the steam for driving a turbine. Beyond the heat exchanger of such a plant everything would be done according to standard practice. Up to the heat exchanger all the design requires new features, among them protection against the extreme radioactivity of everything, including the coolant, that has been exposed to the neutrons.

The chain reacting unit itself can assume many forms. The one essential is that it shall contain a fissionable substance such as uranium, either in its natural state or, if a small unit is desired, enriched with additional U-235 or plutonium. H. D. Smyth, in his official report, has described in some detail how this active material can be combined with a moderator such as carbon or beryllium or heavy water so as to bring about the chain reaction.

The large atomic power plants now used for producing plutonium have in them many tons of natural uranium and graphite. By using uranium containing more than the usual fraction of U-235, chain reacting units have been built that are of much smaller size.

There is, however, a lower limit to the size and weight of an atomic power plant that is imposed by the massive shield needed to prevent the neutrons and other dangerous radiations from getting out. Next to cosmic rays, these radiations are the most penetrating that we know and, for a plant designed to deliver for example no more than 100 horsepower, are enormously more intense than the rays from a large supply of radium or an X-ray tube. To stop them, a shield equivalent in weight to at least 2 or 3 feet of solid steel is needed. There are basic laws of physics that make it appear very unlikely that a lighter

shield can be devised. This means that there is no reason to hope that atomic power units for normal uses can be built that will weigh less than perhaps 50 tons. Driving motor cars or airplanes of ordinary size by atomic power must thus be counted out.

Prominent among the advantages of atomic power are the extraordinarily low rate of fuel consumption and consequent low cost of fuel, the wide flexibility and easy control of the rate at which power is developed, and the complete absence at the power plant of smoke or noxious fumes. With regard to fuel consumption, when completely consumed, the fission energy available from a pound of uranium is equivalent to the energy obtained from burning over a thousand tons of coal. With the prewar price of uranium oxide at roughly \$3 per pound and of coal at \$3 per ton, this would mean the economical use of uranium as fuel if only one part in a thousand of its available energy is used. Actually we should expect the first plants built for producing atomic power to be considerably more efficient than this in their use of the fission energy which would mean a substantial cost advantage in favor of uranium. One must consider also, however, the need to purify and fabricate the uranium into the desired form. For certain types of power plants under consideration, some separated U-235 is required and this is expensive. Attempting to consider all such factors, it appears that the fuel cost of the atomic power plant of the future will nevertheless be small as compared with the corresponding fuel cost of a coal-burning plant.

In considering the economic aspects there are, however, many other factors. It is not really possible for these to be explored until we have actual experience with atomic power plants. First is the capital cost. Clearly, if one must charge against the capital cost what is spent in research and development, this cost is very high indeed. If, however, one looks down the line to a billion dollar a year national industry based on atomic power, the Nation can afford a considerable investment in the research and development required to bring this industry into being. When this development is completed, it appears not unlikely that the cost of building and maintaining a large-scale atomic power plant may compare favorably with that of a coal-consuming plant of the same capacity.

Much remains to be learned, however, regarding the metallurgical and other technical problems involved in constructing a successful plant to transform fission energy efficiently into high-temperature heat. The materials to be used may be expensive. The designs are, nevertheless, essentially simple. An inherent advantage of the atomic power unit is that the heat sources, i. e., the uranium blocks, can readily be maintained at any desired temperature regardless of how rapidly the heat is being removed. This means that a relatively small-size

heater unit will be needed and that corrosion due to excessive heating is controllable.

The terrific blasts produced by the atomic bombs have led to unwarranted fear of accidental explosions resulting from the normal use of atomic power. Explosions such as destroyed Hiroshima cannot occur accidentally. Such explosions must be carefully planned for. The dangers of explosions of the "boiler" type with an atomic power plant are about the same as with a steam plant, which is to say they are practically negligible if the plants are designed and handled by competent engineers.

There is, nevertheless, real possibility of damage to health of the operating personnel from ionizing rays emitted by the plant itself and by all materials that are taken out of the plant. These materials could also become a public hazard. This is the problem of the health of radium and X-ray workers on a grand scale. That the problem can be solved is shown by the fact that in all of the operations of the existing half dozen or more such plants, some of which have now been working for years, not a single serious exposure has occurred. This, however, is due to the thorough inspection and vigilant care given by the health staff headed by Dr. Robert Stone. In some of the experimental work we have not been so fortunate. Until we become much more familiar with nucleonics than we are at present, atomic power plants can be operated safely and serviced only with the help of health supervisors who are familiar with radiological hazards.

All of this points toward using atomic power first in relatively large units where careful engineering and health supervision can be given. An obvious suggestion is its application to the power and heat supply of cities and of large industrial plants. Within 10 years it is not unlikely that the power companies designing new plants for city service will be considering favorably the use of uranium instead of coal for purely economic reasons.

This of course does not mean that atomic power will put coal out of business. Each will have its own field. For small heating units, such as the kitchen stove, atomic power has no place. If our national economy grows as it should, coal as a chemical agent, as for example in blast furnaces and preparation of organic chemicals, will increase in importance.

From the point of view of the national economy the introduction of such a new source of power is a clear gain. If it will lessen the cost of heat and power to our cities, it will be a stimulus to every industry. If it reduces the pall of winter smoke, it will be a boon to us all. If it gives cheap power where industry and agriculture need it but cannot now get it, it will extend our economic frontiers. These are possibilities that lie immediately before us.

3. ATOMIC ENERGY AND OUR WAY OF LIFE

Atomic energy is just one more step along the path of technological progress. It may, however, be the supreme gift of physical science to the modern age. Clearly its value will be determined by the use to which it is put. It is especially worthy of note that, along with other technical advances, the effect of atomic power is to force human society into new patterns. This need for human growth to meet the responsibility of atomic power is the basis of Norman Cousins' striking statement that "modern man is obsolete."

Let me note briefly three such effects of technology on society that can be clearly recognized. These are, first, toward greater cooperation, second, toward more training and education, and third, toward evaluating one's life in terms of service rendered to the community.

First, the society that is adapted for survival in the modern world is one in which an increasing degree of cooperation occurs between diverse groups spread over ever larger areas. As an example, consider the atomic bomb project, in which about a million people of all types and descriptions and spread throughout the Nation worked together to gain a needed result that could be achieved only by a great coordinated community.

In no field is the growing importance of such cooperation more evident than in that of scientific research. Faraday, a century ago, was one of the first professional scientists. Working by himself, he covered the whole field of electricity and much more besides. Sixty years ago Thomas Edison organized what was perhaps the first research team to work with him at Menlo Park. Now our country has thousands of research laboratories. From 1900 to 1940 our universities developed organized research groups for studying specific problems. Astronomers built specialized observatories. Research centers grew for studying diseases. Teams of physicists built cyclotrons and surveyed cosmic rays over the world. When the war came cooperative research became of greatly increased size and effectiveness.

The development of the methods for producing plutonium is typical. At the peak there were engaged on this one problem roughly 5,000 laboratory workers in more than 70 locations studying its different aspects. Not only theoretical physicists and nuclear chemists were needed. Equally vital were corrosion experts and metallurgists and haematologists and meteorologists, laboratory technicians, mechanics, and office workers of many kinds. No one person could be skilled in every field or understand even the meaning of the answers to the many problems. But somehow the group mind integrates such knowledge into the useful form that results in a process that successfully produces plutonium.

There remains, happily, a valuable place for the individual research man who masters and advances his own limited field of study. His specialty, however, is of little value except as a part of a broader field. More and more we find that even in a limited field a team of men with different specialties working together does the most effective work. New thoughts develop in their discussions. More refined techniques are available. A team which thus supplies a combination of originality and special skills is the pattern toward which research is moving.

Cooperation is thus the very life blood of a society based on science and technology. Such a society is necessarily made up of specialists, not only scientists and engineers, but skilled laborers, salesmen, administrators, educators, and legislators. Working alone such specialists are useless. When their work is coordinated they form a society of enormous strength. It is a major source of our Nation's vitality that we have so many diverse elements in our population. Each has its place among the many specialties. What the society of an atomic age cannot permit is the development of antagonisms between these groups that will prevent effective cooperation. To love our neighbors is becoming the condition of survival. And our neighbors with whom we work are to be found in all divisions of society throughout the entire world.

As the second evident effect of technology on society, consider the need for ever-increasing training and education. It is because of the mechanical skill of many millions of workers, the know-how of our many technical men, and the administrative skill of our industrial and military leaders that our country has come out ahead in this war as in the last. It is no disparagement of the American engineers who have done these great tasks to point out that most of the new wartime developments that have led to victory, such as radar, submarine detection, rockets, and the atomic bomb, have had to be led by men whose scientific knowledge is far in advance of that supplied by our technical schools and industries in the training of engineers. To compete in the modern world more people need more training. Nor is technical training all that is required. Of greater importance is more education for leadership. In a democratic society that is forced into a position of world prominence, our citizens as well as our leaders need to understand the problems and human needs of all the nations.

This pressure for more training and education applies at all levels. Automatic machinery performs an increasing number of routine jobs. The demand for skilled mechanics to make the machines is thus increasing while that for unskilled labor falls off. The growing complexity of society multiplies rapidly the demand for all kinds of

persons trained to keep the work coordinated. These range from typists to administrators. Of those whose over-all view of the needs of society is adequate to guide wisely an industry or the growth of a community there is an acute shortage.

The result is more students wanting more extensive education in schools and colleges. Professional schools are becoming graduate schools. More research men will want to carry their studies beyond the doctor's thesis. The interruption of our college education during the war places our Nation at a temporary disadvantage with regard to highly trained young men and women and is for the moment keeping down the enrollment in our advanced classes. All indications are, however, that the postwar pressure on our institutions of higher learning will increase and continue. There is growing interest likewise in all aspects of adult education as our citizens strive to keep themselves abreast of the rapid changes of the times.

The third and perhaps the most remarkable trend is an increasing concern that one's activities shall contribute to the welfare of society. It is more difficult to establish this trend by citing examples than it is to show the increase of cooperation and of education. But it is, I believe, no less real. The ancient high regard for the "holy man" who retired to a monastery and separated himself from society finds little sympathy in our modern life. Reading of American colonial history shows that the freedom for which our forebears fought was primarily the right to live their own lives in the pursuit of happiness without unnecessary restrictions, not primarily the opportunity to shape a better society. Now both capital and labor strive to justify their position in terms of the usefulness of their contribution to society, and our Nation has fought a war with unparalleled unanimity because our loyalty to the common cause made us ready for any sacrifice.

We have not had in this country prominent movements similar to that in Germany, where the youth was whipped to patriotic ardor by the call to lose one's self in the greater good of the state. Nor has any "cause" in this country perhaps met with the wide response the Russians have given to communism as a political system in which each person consciously works for the good of all. Yet Americans respond to many calls to service. As members of scientific societies, we are aware of our own increasing attention during the past generation to the social responsibilities of science and scientists. The present active concern of the scientists about the political disposition of the atomic energy problem is apparently only a representative example of the anxiety of everyone in the Nation that with the great issues with which humanity is faced his own actions may help rather than hinder a good solution. The greater powers placed in our hands

by technology seem indeed to make us more acutely aware of our responsibility to use these powers for human ends that go beyond ourselves.

Typical of the forces working in this direction is recognized need that our form of society must attain its fullest strength if it is to survive in the fierce competition of the postwar world. We have come to realize however that our strength lies in the many millions of our citizens who are working efficiently and loyally at the Nation's tasks. Widespread education, encouragement of each individual to seek for the place in the game where he can play best, opportunity for advancement and leadership—all these have helped to strengthen our society. Self-preservation demands that all possible effort be given to enable and encourage every citizen of the country to contribute his best to the needs of the Nation. To attain this result, cultivation of the spirit of service is of first importance.

The evolutionary law of the survival of the fittest applies to societies as well as to individuals. According to this law the society of the future will inevitably advance along these lines of cooperativeness, of education, and of individual concern with service toward the common welfare. If selfish interests or an ill-adapted form of government should prevent our growth along these lines, some other nation or group that can develop thus more rapidly will pass us by.

You will note that these factors which give strength to society are precisely those that characterize the highest type of citizen. Cooperation: he likes to work with others on a common task. Education: he has learned to do his own useful task and to share intelligently in solving public problems. Service: the central objective of his life is to contribute to the common welfare the maximum that his abilities make possible. These also are the factors which make life of greatest value to the individual himself.

My point is this: the release of atomic energy is merely the most recent important step of that steady progression of science that is compelling man to become human. He must pay careful attention to cooperation, education, and service for the welfare of society if he is to thrive under the conditions that science imposes. If we will let ourselves grow as thus indicated, the civilization of the atomic age promises to be the richest that history has known, not only with regard to material bounty, but also in its cultivation and appreciation of the truest human values.

How then are we justified in describing atomic energy as a human asset?

First, atomic energy now supplies for the first time weapons which make it possible for a centralized world government to prevent wars between nations. Having made war intolerable because of its enor-

mous destructive power, it thus opens the way for an international organization to prevent war from ever occurring again.

Second, atomic energy is now a source of useful new materials produced by transmutation. It promises to supply us with heat and power available in large quantities wherever needed and thus to open new economic frontiers. New advances in medicine, in industry, and in science are on the horizon.

Third, as the most recent great step in the long progression of advances in science and technology, the advent of atomic energy is forcing mankind along the difficult road to greater humanity. Growing cooperation, education, and spirit of service are evident trends.

The present is thus a time for hope. True, the atomic bomb has brought us face to face with the fact that continued world strife will mean disaster and death. It is, however, likewise true, and much more worthy of attention, that the way is now open as never before for the world to reach a true unity, with world peace a necessity that can and will be attained.

When our first parents ate of the fruit of the tree of knowledge, they became as gods, knowing good from evil. Much as they longed to return to the garden of innocence an angel with a fiery sword stood in their way. Their only hope for peace lay in work to make the earth give them a fuller life. Somehow the marvel occurred that in their work they became human souls who shared the task of their Creator and came to be called His children.

The same angel with the same fiery sword prevents us from returning to a pre-atomic age. We have no choice but to use our great new powers in the effort to build a better world.

In the fierce competition between social systems in the atomic age, the need for strength demands that we enable every citizen to contribute to the common welfare as his abilities may permit. Permanent peace can now be secured if we will work for it. Increased prosperity with broader horizons lies before us. Greater development of the human spirit is the inevitable consequence of the increased responsibility for using our new powers. These are among the greatest of human goods.

THE SCIENTIFIC IMPORTANCE OF X-RAYS¹

By L. HENRY GARLAND, M. D.²

[With 2 plates]

Come, come, and sit you down; you shall not budge;
You go not, till I set you up a glass
Where you may see the inmost part of you.
(*Hamlet, act III, scene 4, lines 23-25.*)

The discerning English dramatist wrote these amazingly prophetic lines some 300 years before a modest German physicist announced the discovery of a "new type of rays." Yet, had he known, Shakespeare hardly could have penned a more apt description of a fluoroscopic examination—aided, it is granted in this instance, by a mirror, in which the good Queen of Denmark might "see her inmost part." To continue the remarkable coincidence, the Queen, like many an apprehensive patient, replies to Hamlet:

What wilt thou do? Thou wilt not murder me?

And Polonius cried forth:

What ho! help, help, help!

Before the days of shockproof X-ray equipment, such a scene might have taken place in a radiologist's office; today it should be a rarity (unless Polonius were confronted with the statement for an unusually prolonged and complicated series of examinations).

In the half century which has elapsed since Roentgen's announcement there have been many developments in medical science which, at first glance, might seem to dwarf the tremendous importance of the discovery of X-ray. These developments include the perfection of antitoxic sera, of remarkable antibiotic agents (the sulfa drugs, penicillin, and similar molds), of stored blood or blood derivatives, and finally of planned atomic disintegration. Yet we believe it is safe to hazard the guess that in another 50 years we still shall look upon the X-ray as one of the developments of major scientific import of all time,

¹ Reprinted by permission from *Electrical Engineering*, vol. 64, No. 12, December 1945.

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as well as one of the most valuable weapons for medical care. We shall look back and thank the pioneers in physics, electricity, radiology, and general medical pedagogy who made equipment practicable and who encouraged physicians to specialize in the field of X-ray diagnosis and treatment.

GENERAL CONSIDERATIONS

To appreciate the importance of X-rays it is desirable that certain basic facts be kept in mind. These rays are penetrating radiations corresponding to light rays but having much shorter wave lengths. They may be used in a manner similar to light rays for the inspection of some materials and, by virtue of their peculiar properties, for the analysis of others. Gross inspection methods include simple roentgenography (or X-ray "photography") and roentgenoscopy (or X-ray fluoroscopy); detailed inspection methods include various other means such as microradiography, Roentgen spectroscopy, Roentgen diffraction, and so forth. In practice, X-rays usually are generated by allowing a stream of high-speed electrons to impinge upon a metal target. They have wave lengths of from 10.0 to 0.01 angstroms, and effect a sensitized film in a manner similar to that of light rays. They also cause certain substances to fluoresce. The materials through which they pass are ionized and give rise to scattered X-rays. Because of this ionization, the rays are of use in the treatment of certain medical conditions. X-rays can be reflected, refracted, and polarized by special means (including the use of crystals).

The principal use of X-rays lies in their ability to penetrate opaque objects. Such objects arrest the rays approximately in direct proportion to their densities. Substances of low atomic weight such as cotton, gauze, and aluminum, are traversed readily by the rays, while other substances such as bone and heavy metals are opaque, and cast a dense shadow on a sensitized film. Some materials are transparent to light rays but opaque to X-rays (for example, a plate of lead glass).

In the radiographic examination of materials (both animate and inanimate) it is important to remember that the delineation of an object depends on its differing in density from its surroundings. Unless such difference exists, the outline of the object cannot be shown on ordinary roentgenograms. A simple example of this is the demonstrability of the heart in X-rays of the chest. Surrounded as it is by air-filled lungs, the heart is readily visible in chest films. However, if nature had placed it in the middle of the liver, no distinct shadow would be cast as the liver is of approximately the same density.

Under ordinary circumstances, X-rays are not directly visible and require a specially prepared surface for their detection (a fluoroscopic screen or sensitized film). We use the adjective "ordinary" because you actually can see X-rays with a little training and practice.

Unfortunately, if you look at them sufficiently long, you will lose your eyelashes, and probably your eyebrows, if not most of your hair. This is because of the destructive effect of large amounts of X-rays on the hair follicles and other living tissues. However, it is safe to gaze at the rays for a few minutes, using a small beam (perhaps 1-inch diameter). One must sit in total darkness for some 30 minutes before he can appreciate the faint fluorescence produced by the rays on the human retina; one is then able to see small lead objects placed between the X-ray tube and the human eye, and, if one has an opaque lens (cataract) or cornea, he can ascertain whether or not the optic nerve is intact. The method is used occasionally by radiologists, at the request of eye specialists, to assure that the patient has an intact retina and nerve before surgical procedures on the cornea or lens are performed. It is to be noted that objects will seem upside down, since the focusing power of the human lens will be ineffective with X-rays.

The action of X-rays on photographic film is similar to that of light rays. Ordinary X-ray films are coated on both sides with a silver halide emulsion, especially sensitive to the violet range of the spectrum, because they are used mostly with double intensifying screens which glow with that color. These screens consist of thin pieces of cardboard coated with calcium tungstate and a protective transparent film. They are placed in a special bakelite or aluminum-fronted frame, and for satisfactory results must make perfect contact with the film. Special nonscreen films may be used for improved detail, but are from 5 to 10 times slower than screen films. The modern film has a cellulose-acetate base (with no greater fire hazard than paper). The finished roentgenogram is a negative image and is studied in a flashed opal glass illuminator.

The fluoroscopic screen usually is made with zinc sulfide because it must carry an image to be viewed directly and this chemical fluoresces in the color range to which the eye is quite sensitive (yellow green). Roentgen's original screen was made of barium platino-cyanide, which was much less efficient than the present type. All fluoroscopic screens must be covered with lead glass to protect the operator from exposure to X-rays. The operator must "adapt" his eyes prior to examination by remaining in a darkened room for several minutes or by wearing special goggles before beginning the work.

A beam of X-rays consists of electromagnetic radiations of various wave lengths. If of very short wave length they are of high penetrating power; if of very long wave length they may penetrate only a few millimeters of tissue. The quality of a beam of rays may be measured by various methods, the most convenient one in ordinary practice being the determination of their absorption by some material such as copper

or aluminum. A spectrometer can be employed, but is too time-consuming and troublesome for routine use. The quality is expressed as the thickness of an absorber which reduces the intensity of a given beam to one-half its initial value, and the resulting figure is known as the half-value layer for that beam. For low-voltage rays (up to 20 kilovolt) cellophane may be used as the absorber; between 20 and 120 kilovolt, aluminum; between 120 and 400 kilovolt, copper; and for more than 400 kilovolt, lead or tin. A refinement of the method is to record a second half-value layer, the ratio of the second to the first being used as an index of homogeneity. It is to be noted that the expression half-value layer is only part of the description of the quality of a given beam; for scientific purposes one also must specify the nature of the target material, the tube wall, and the generator wave form.

The quantity of X-rays in a given beam at a given point may be measured by recording the ionization in a fixed volume of air or gas at that point. The "roentgen" is the unit of X-ray quantity and is defined as "that quantity of X or gamma radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying one electrostatic unit of electricity of either sign." The mass of 1 cubic centimeter of air at 0° centigrade and 760 millimeters of mercury is 0.001293 gram; in biological work, 1 roentgen equals 83 ergs per gram of tissue. The rays usually are measured by an electroscope attached to a small thimble chamber composed of a special light plastic material. It is of interest to note that the almost universally used instrument at the present time is a "condenser Roentgen meter" designed and manufactured in Cleveland, Ohio.

X-RAYS IN SCIENCE

The importance of X-rays to science in general is so great that a volume would be necessary to describe it. However, a few of the more interesting applications of X-rays will be mentioned in this article and an attempt made to give a clue to their true value. For the sake of brevity the sciences will be grouped into a few general categories.

Anatomy and physiology.—The importance of X-rays to anatomy, comparative anatomy, paleontology, and associated sciences is now well appreciated. However, it is not realized generally that the modern method of teaching anatomy to medical and other students involves the use of roentgenological demonstration of the skeleton and its various associated soft parts, both in the cadaver and in the living subject. In this manner the appearance and behavior of bony and other structures in the living is demonstrated in a way never before possible. The study of the skeletal development in vertebrate embryos is facilitated enormously by Roentgen methods. The anatomy of small and large animals is revealed in zoological work. The status and often the

diseases of mummies may be determined without opening the wrappings or even the sarcophagi. Genetics has been furthered by studying the behavior of many species, notably *Drosophila melanogaster* (the common fruit fly) following exposure to specific quantities of X-rays (with the production of subsequent mutations of certain types).

Physiology is greatly indebted to roentgenologic methods, notably in connection with the study of the alimentary tract, the circulation of the blood, and the functioning of moving parts, especially joints. X-ray "movies" as well as fluoroscopy and "still" films have been used extensively in this field. As an example of their value in one small department the X-ray (kymographic) determination of cardiac output can be cited (2).³

An X-ray film is made of the subject's chest, in the erect position, at a measured distance (say 5 or 6 feet), using a lead grid between the patient and the film. The exposure takes about 2 seconds' time and the film is moved slowly downward a distance of 12 millimeters during the exposure. When the film is dried, the outline of the heart appears as a serrated border, the "peaks" representing the shadow in maximum expansion and the "valleys" in maximum contraction. The peaks are joined by one line, the valleys by another. The rest of the heart shadow is completed as shown in plate 1, figure 1. The area in these two phases then is measured with a planimeter and the figures corrected for distortion. The corrected figures then are converted into volumes according to a table established from experimental and cadaver work. The difference in volume between expansion and contraction gives the output per beat. In many normal subjects the average stroke output per ventricle is 60 cubic centimeters; a person with a rapid pulse tends to have a smaller, and one with a slow pulse a correspondingly larger output. Therefore, it is more informative to speak of the output per minute than the output per stroke; this in turn varies with body size, which may be expressed fairly simply in terms of total body surface. The number of liters of blood pumped per minute per square meter of body surface is termed the cardiac index. This index thus may be found by using this particular X-ray method. (Needless to say, there are other methods of determining this index, but the roentgenkymographic one is a simple and reliable one when correctly used.)

Our knowledge of the functions and behavior of the alimentary tract in health and disease is largely dependent on the use of Roentgen methods of examination. Some of the earliest investigators in this field have been American physiologists who did their original work on cats (to whom they fed bismuth in milk, and so forth). Food also

³ Numbers in parentheses indicate references at end of article.

may be used, provided it is opaque to the rays. On an early morning walk near San Francisco several years ago, I came across a plump horned toad. Having a little time to spare that day, I brought the toad into my fluoroscopic room and placed it on the table. I then captured a common house fly and dusted it with barium sulphate. After setting the tasty meal beside the toad I turned on the X-rays and watched the inevitable and fascinating sequence of events. The barium cast just as good a shadow in the toad's stomach as it does in the human, and the progress of the meal could be studied easily.

Physics and chemistry.—The use of X-rays in the sciences of physics and chemistry and all their innumerable ramifications is an ever-expanding chapter in X-ray history. The gross analysis of many materials may be performed in part by roentgenoscopy or roentgenography, and the detailed analysis by methods such as Roentgen diffraction, crystallography, or electron microscopy. The diffraction method of measuring small objects is well established. The principle depends on the fact that a beam of light or X-rays which has traversed a collection of small objects is seen surrounded by a series of rings or diffraction spectra, from the diameter or pattern of which the size of the object can be calculated. A familiar example is the ring visible around lights on a misty night, the diameter of which is determined by the mean diameter of the mist particles. The interpretation of X-ray diffraction patterns in terms of the ultimate structure of crystals and solids has its foundations in crystallography. By such methods it is found that rubbers, plastics, and fibers, although superficially different, are intrinsically similar materials. X-ray studies also have assisted greatly in analyzing the structure of the higher polymers. The essential features of such diffraction apparatus are:

1. A source of X-rays.
2. A device to limit the rays to a beam of minimum divergence.
3. A holder to support the test specimen in the beam.
4. A means for recording the X-rays diffracted from the sample of critical angles (determined by the crystal structure of the samples).

A recent issue of *Electrical Engineering* included a description of a method of X-ray analysis of unknown chemical substances by employing a new photoelectric roentgen intensimeter (1). The meter is said to be so delicate that if the X-rays are passed through a pile of 100 sheets of paper, the difference in absorption caused by adding or subtracting a single sheet can be recorded.

As a direct result of investigations in physics and chemistry there are numerous industrial and commercial X-ray developments which include the following:

1. The examination of various complicated appliances, such as radio tubes, without the necessity of breaking open the tubes.

2. The examination of castings and welds.
3. The examination of packages and personnel for concealed materials.
4. The examination of edible materials for defects or impurities (such as candy bars and oranges).
5. The behavior of solids and liquids under projectile bombardment (such as high-speed roentgenography of bullets).

The roentgenographic examination of metal parts in connection with the airplane industry is said to have used up more film per month during the last few months of the recent war than was used in all medical procedures in the United States during the same period. The importance of skilled interpretation of these roentgenograms and of adequate protection for the employees operating the X-ray equipment obviously is great.

Since the early days of X-ray development, packages, clothing, and even personnel have been inspected for contraband and other illegally possessed materials. Packages and similar objects may be inspected without harm, provided they do not contain unprocessed film or other sensitized material. Individuals may be examined only under stringent conditions, as exposure of large amounts of the body to X-rays, especially if repeated, is fraught with ultimate danger to the individual; possibly resulting later in skin damage, anemia, or infertility.

It is to be recollected that metals and other materials may be radiographed either with X-rays or radium rays. It is therefore appropriate to consider a few aspects of radioactive substances, as many of them have properties analogous to those of X-rays. Radium rays are of three general types:

1. Alpha rays, which are positively charged particles of very low penetrating power, being stopped by a sheet of ordinary paper.
2. Beta rays, which are negative electrons, of moderate penetrating power, stopped by a thin metal filter (2 millimeters of brass or 0.5 millimeter platinum or their equivalent).
3. Gamma rays, which are electromagnetic radiations (photons) of considerable penetrating power, the hardest ones traversing several centimeters of lead.

Because of their different charges, these three types of rays can be separated in a magnetic field. The alpha rays are deflected slightly in one direction, the beta more strongly in the opposite direction, and the gamma not at all. Radium disintegrates slowly, its half period being 1,590 years. For medical purposes it usually is kept in small containers in the form of a radium salt. Many of these containers can be placed together and the group then used like an X-ray tube.

Since the work of Rutherford, in 1919, we have been able to produce artificially radioactive substances. One method of doing this is to use the cyclotron, by means of which the nuclei of atoms are transformed into new unstable substances. High-speed protons, deuterons, and neutrons have been used to transform most elements. The resultant

radiations are of many types (alpha, beta, gamma, neutron, and positron). Many biologically useful radio elements are produced by deuteron bombardment and include radiophosphorus, radiosodium, radioiron, radioiodine, and radiostrontium. These substances can be administered to patients and their exact method of localization and storage in the human body studied by means of Geiger counters and similar apparatus. In this manner the metabolism of certain living tissues, in both health and disease, can be studied more completely than ever before. For example, totally new information concerning the need for and method of use of iron in the human body, in conditions like anemia, has been obtained.

An indirect development of high-voltage tubes in physics is the electron microscope which permits much higher magnifications of minute objects than are feasible with optical microscopes. With this instrument the image of the object is viewed either on a fluorescent screen or is recorded on a photographic film. Recent developments include modifications by which the instrument may be used either as a diffraction camera or a microscope. Stereoscopic electron micrographs can be made. The usual electron microscope operates at about 60 kilovolts, but there is a small table model operating at 30 kilovolts. The structure and behavior of viruses has been studied for the first time, and the detailed structure of bacteria has been revealed. Chromosomes, the tiny rodlike particles that bear the major responsibility for inherited characteristics, may be examined, and by means of ingenious methods the actual location of certain specific genes in a number of chromosomes has been determined.

Biology.—X-rays have been used in most of the various biological sciences, notably in botany and zoology. The architecture of many forms of plant life have been studied by macroradiography as well as microradiography. Mutations have been produced by bombardment of seedlings and rootlings with X-ray, and new hybrids successfully developed. In fact, one physician insists that a special type of begonia he grows is a direct result of irradiation of a former plant. He gives no credit to Mendel's cosmic ray but, unfortunately, I am not sufficiently familiar with botany to know whether or not he is correct.

In zoology, several forms of animal life have been studied with X-rays. With the larger type of animal one naturally has to make segmental studies. About a generation ago an ailing elephant at the London zoo was subjected to X-ray examination. The tired pachyderm lay on her side and had her torso marked with chalk into a series of rectangles, each a little less than 14 by 17 inches in size. These then were numbered in sequence and a series of roentgenograms made. We cannot vouch for the quality of the films made through the thicker parts, but those of the extremities which we saw were quite good. Race

horses, greyhounds, parrots, and other domestic pets frequently are subjected to examination in connection with injuries, foreign bodies, and certain diseases. Before the development of shockproof apparatus, cats were particularly difficult to X-ray as they have a strong dislike for the hair-raising qualities of the corona from exposed high-voltage wires.

Miscellaneous.—One of the lesser-known but more valuable uses of X-rays is in connection with art. Many pigments contain lead and other radiopaque salts and the roentgenogram of a canvas often reveals shadows different from those on the visible painting. Areas of over-painting, alterations, and erasures can be detected. The authenticity of some old masters has been proved and of others disproved by such means. A recent refinement includes sectional radiography of the canvas in which, by keeping the tube and film in motion, a very fine layer of the painting can be registered to the exclusion of other layers.

TABLE I.—*The electromagnetic spectrum*

Type of radiation	Range of wave lengths	Range of frequencies
Electrical waves	1,000,000 to 20 kilometers	10^4 to 10^4
Radio waves	20 to 0.01 meters	10^4 to 10^{11}
Infrared rays	120,000 to 7,700 angstroms*	10^{11} to 10^{15}
Visible rays	7,700 to 3,900 angstroms	
Ultraviolet rays	3,900 to 1,800 angstroms	
X-rays	10 to 0.01 angstroms	
Gamma rays	0.1 to 0.02 angstrom	
Cosmic rays	$0.00001 \pm$ angstrom	

* 1 angstrom = 10^{-8} centimeters; 100,000,000 angstroms = 1 centimeter.

X-RAYS IN MEDICINE

The importance of roentgenologic methods in medicine, dentistry, and allied sciences is increasing continually. They permit the examination of parts of the body hitherto inaccessible to study and the detection of disease at a stage when it may be cured readily. They extend the physician's eye to an incalculable distance. They are also of use in the prevention of disease and in its treatment. (A small precancerous skin nodule, keratosis, may be cured before it develops into a malignancy; established, localized, accessible cancer can be destroyed.) Our knowledge of many diseases such as stomach ulcer, lung tuberculosis, and bone cancer has been entirely revolutionized and reoriented since the discovery of X-rays. They have provided an impetus to investigation and research in preventive medicine such as no other weapon ever placed at the disposal of the doctor.

One might arrange this section according to the various medical specialties, but I think it will be of more interest to nonmedical readers to consider the importance of the rays according to each of the various

systems of the human body. However, it is timely at this point to acknowledge the debt of roentgenology to members of the specialties outside of its own field, physicians who have contributed greatly to the refinements of many techniques in diagnosis as well as treatment. The reader should know that there are now "national qualifying boards for specialists." These boards examine eligible graduate physicians and certify those who pass successfully. At the present time there are boards in the following branches of medicine:

- | | |
|---------------------------------|-------------------------------|
| 1. Anesthesiology. | 9. Pathology. |
| 2. Dermatology and syphilology. | 10. Pediatrics. |
| 3. Internal medicine. | 11. Plastic surgery. |
| 4. Neurological surgery. | 12. Psychiatry and neurology. |
| 5. Obstetrics and gynecology. | 13. Radiology. |
| 6. Ophthalmology. | 14. Surgery. |
| 7. Orthopedic surgery. | 15. Neurology. |
| 8. Otolaryngology. | |

X-ray diagnostic methods involve first and foremost intelligent use: one case may be diagnosed quickest without X-rays at all; the next may need only fluoroscopy; the third, fluoroscopy, roentgenograms, and special-section techniques; the fourth may require repeated roentgenograms. Only a trained physician knows the correct answer to these questions: only a trained physician can be economic in the exposure of your tissues to a radiation known to be noxious. The wise layman selects his physician-radiologist according to his experience or ability, and not according to the newness or extent of his equipment. In assessing the value of a roentgenogram it is important to remember that it is just a shadowgraph and not a true photograph and as such is subject to erroneous interpretation. Furthermore, the roentgenogram is a projection on a flat surface of everything on every plane between the X-ray tube and the film. Thus it is desirable that the interpreter familiarize himself with the projected appearance of normal structures of various shapes. Multiple views, preferably at right angles, usually are essential; stereoscopic roentgenograms frequently are necessary. The examination of moving parts such as the stomach, heart, or diaphragm frequently requires fluoroscopy as well as multiple films.

There are many shadows in roentgenograms of healthy persons which cause errors in interpretation. These include the normal epiphyseal or growth line in bones (often mistaken for a fracture), the overlapping of a bony margin, or the slender canal of the artery to the bone. The existence of a congenital fissure or cleft also may be mistaken for a fracture. Calcium deposits are fairly common in various tissues; they are normal findings in rib cartilages, laryngeal cartilages, and certain other areas, but occasionally they are mistaken for tuberculous lesions, foreign bodies, and so on. This is one of the

reasons why a consultant roentgenologist may require stereoscopic or other additional projections even though you present yourself with a perfectly good film made elsewhere only a few days before. A small wart on the back may be projected on a film in a manner identical with that of a kidney stone or gall stone. Visual examination of the undressed patient or stereoscopic projections should prevent an error being made. In general, it is advisable for persons to be undressed when having X-rays taken, since objects such as earrings have been mistaken for misplaced toothroot fragments, buttons for gallstones, and the edge of folded clothing for fractures. Faulty darkroom technique sometimes results in undeveloped or fogged areas of films which can suggest (in chest films) pneumonia or (in films of the limbs) diseased bone, even to the initiated.

The use of X-ray methods in medical diagnosis may be outlined in relation to the various systems of the body.

Alimentary system.—X-ray examination of the alimentary system permits the early diagnosis of a vast number of common disease conditions, ranging from adhesions to volvulus. Both fluoroscopic and film examinations are usually essential. The fluoroscopic examination discloses facts regarding the mobility and function of organs which cannot be obtained from films alone; the films in turn reveal detail of structure which cannot be appreciated on the fluoroscopic screen. The value of either method depends on the skill, patience, and experience of the examiner. When it is a question of a condition such as early stomach cancer, the examination may have to be repeated two or three times before a reliable opinion can be rendered. For the upper part of the system (the gullet, stomach, and small intestine) it is necessary for the patient to come fasting. He is given a drink of barium sulfate suspended in water and the appearance of these portions of the tract is studied under the fluoroscope. Patients often complain at the chalky taste of the bariumized water. The reason that flavoring agents are not used is that in some persons they stimulate large amounts of gastric secretion which dilutes the test meal undesirably. In the early days of roentgenology the barium or bismuth used to be given in flavored preparations. However, if these contained much milk or cream, stomach emptying would be (physiologically) delayed. If they contained much sugar, stomach emptying would be hastened. These conditions often resulted in erroneous conclusions as to the presence of gastric stasis. In the average case 4 ounces of barium sulfate (by weight) are given in about 8 ounces of water. This eventually mixes with the other contents of the intestinal tract and does not require laxation for its natural ejection.

The lower portion of the alimentary system normally is examined by barium enema. Sixteen ounces of barium sulfate are suspended

in 2 quarts of warm water, with the addition of some medium such as acacia solution to maintain suspension during the procedure. After fluoroscopic and roentgenographic examinations the patient evacuates the suspension.

Conditions diagnosable by X-ray include varicose veins in the gullet, ulcers, and tumors in the stomach or duodenum. Before the days of X-ray, duodenal ulcer was considered a rarity; a person with severe and prolonged indigestion was usually diagnosed stomach ulcer. Since the development of Roentgen methods it has been found that most such cases are actually due to duodenal ulcer, the latter being over 20 times as common as gastric ulcer. This was one of numerous revolutionary findings during the first two decades of this century.

Gastric cancer is one of the most common and serious malignant tumors in man; unfortunately it tends to be asymptomatic in its early stages and therefore its presence is not manifested until it is pretty well advanced. Persistent disturbance of digestion in men over 40 renders X-ray examination of the stomach advisable. The growth shows as a small intrusion on the barium shadow or as a small zone of immobility of the stomach wall.

The normal appendix usually is visible at some time during X-ray examination of the intestinal tract. It may be seen to fill and empty but if it does remain filled for some days this finding alone is not of grave importance. The X-ray evidence of acute disease in the appendix consists of marked local tenderness, absence of or incomplete filling, delay in the passage of the barium in the adjacent terminal inches of small bowel, and, occasionally, a local inflammatory mass. However, the diagnosis of acute appendicitis is more reliable when made by methods other than radiological ones.

X-ray examination is invaluable in the study and elucidation of the various diseases of the colon.

The liver and spleen are normally visible in most abdominal roentgenograms. Their visibility may be enhanced by intravenous injection of thorium dioxide sol (thorotrast), a drug which has the property of depositing itself in the small cells lining certain portions of the liver and spleen (the reticuloendothelial cells). The thorium is opaque and aids in the diagnosis of certain tumorous and cystic diseases of these organs. After 7 years, thorium degenerates into a mildly radioactive product, but the amount necessary for ordinary examination has been shown to be so small that no harmful late radioactive changes develop. Another area of the alimentary tract which may be examined by selective methods is the gall bladder. If you ingest a suitable iodine preparation, the material will be excreted in your bile and will be concentrated in the gall bladder; provided the

duct between the liver and gall bladder is not blocked and you remain fasting. This test is a valuable method for the detection of non-opaque cholesterin stones in the gall bladder; indeed, it is the only method by which such may be diagnosed preoperatively.

Cardiovascular system.—The accurate determination of heart size in the living human being can be made only by roentgenological methods. It is to be noted, in passing, that this is not always a very important factor, since cardiac function rather than size governs most healthy lives, and function can be assessed by many means much more accurate than roentgenologic ones. However, the problem of heart size does come up in some individuals and Roentgen methods are then invaluable. Correction should always be made for the amount of magnification present, the phase of respiration in which the patient happens to be during the exposure, and similar items. As in the case of the alimentary tract, complete examination of the cardiovascular system involves both fluoroscopy and roentgenography. In recent years the use of opaque substances has permitted the outlining of the individual heart chambers in the roentgenogram and the study of the circulation in a manner one could scarcely have even dreamed of 50 years ago. Besides giving information concerning the size, shape, position, and mobility of the heart, Roentgen methods also may disclose the presence or absence of coronary disease and its sequelae. Records of the beating heart may be obtained on a single film by means of kymographic apparatus and deductions as to the presence of localized areas of heart-muscle disease deducted therefrom. The condition of the arteries and veins in the extremities can be studied by means of both plain films and films made with contrast media and the presence of varicose veins in the deep venous circulation of the leg can be detected and unnecessary operations avoided.

Central nervous system.—Medical advances in the diagnosis and treatment of diseases of the brain, spinal cord, and peripheral nerves is one of the most interesting chapters in modern science. The normal brain casts no distinguishing shadow in the routine roentgenogram. However, by very simple methods, its outlines can be revealed. This consists of performing a spinal puncture (in the lower portion of the back), withdrawing from 75 to 150 cubic centimeters of cerebrospinal fluid, and injecting in its place a corresponding amount of air. Upon placement of the patient in an erect position this gas will ascend into the cerebrospinal fluid pathways around, between, and in the various lobes of the brain. Several plain or stereoscopic roentgenograms then are made from various angles, with the patient both erect and horizontal. The air absorbs during the next few days and is replaced by normal fluid. By this method various types of brain injury, brain disease, and tumors may be detected. Considerable experience is desirable in interpreting these pneumo-encephalograms.

The spinal cord may be studied by similar methods, or by the injection of radio-opaque contrast media into various portions of the spinal canal. The media most commonly used at the present time are preparations containing iodine (iodized poppy-seed oil and ethyl iodophenylundecylate). About 3 cubic centimeters of the opaque oil are injected in the lower lumbar area and the patient is fluoroscoped on a special table. By tilting the body up and down, the lake of opaque oil can be made to traverse the spinal canal. Indentations and certain other alterations of its shadow will disclose the presence of ruptured disks, tumors, and so forth.

Genito-urinary system.—It is now possible to examine the outlines of virtually every portion of the genito-urinary system. One can determine the function of each kidney following intravenous injection of an iodine salt selectively excreted by the kidneys. The seminal vesicles and ducts may be outlined by contrast media. Similarly, the cavity of the uterus and the slender canals of the fallopian tubes can be shown. In this manner an extraordinary variety of conditions, normal as well as abnormal, may be detected. The number, size, and approximate age of infants in utero may be told. The exact alterations in the shape of the fetal bones during the actual process of birth have been studied by serial roentgenograms. The remarkable molding and elongation of the fetal skull have been shown, as well as the disposition of the fetal limbs and placenta. The latter has been studied by arteriographic injection of opaque media and valuable information as to the uniovular or multiovular nature of twins ascertained. Abnormal gestations have been diagnosed correctly in time to save the mother an unnecessarily prolonged pregnancy or labor. These cases are some of the most tragic incidents that a radiologist encounters. The normal fetal skeleton does not contain sufficient calcium to cast a clear shadow in routine roentgenograms before a gestation period of 12 weeks. Within increasing accuracy after that time the fetal parts may be shown. Attempts have been made to determine the sex of the fetus by X-ray methods, but no practical method has yet been found. Extensive studies have been made on the influence of the shape as well as the size of the female pelvis on spontaneous delivery. Female pelvises are classified into four general types, based on their shape. By careful Roentgen examination, the probability of easy or difficult labor can be prognosed with considerable accuracy in selected cases.

Osseous system (bones and joints).—The first use of X-rays was in the examination of cases of suspected fracture. From that day its uses have been extended to include the study of bone growth, bone tumors, joints, tendons, bursae, and adjacent structures. In the correct diagnosis of all bone conditions, and in the treatment of many of them, X-rays are essential.

The detection of a gross fracture in an ordinary roentgenogram is a simple matter; the detection of fine or fissure fractures is often extremely difficult. An important example of this is in injuries involving the wrist, probably the most commonly injured area in the body (see pl. 2, fig. 1). One type of "sprain injury" results in fracture of the scaphoid or navicular bone, a small bone in the wrist joint. This bone has a very critical blood supply. If injured, healing requires immediate and complete immobilization for many weeks. Fractures of this bone are often difficult to detect except in films of the highest technical quality; three or four views may be necessary before the crack can be confirmed or excluded. If overlooked, and the wrist is not immobilized, most of these cases result in nonunion and chronic arthritis in the wrist joint, a serious source of disablement in laborers. Attempts have been made to restore the function of the joint by removing the two broken pieces of scaphoid and replacing them with a synthetic bone (made of a biologically tolerable metal such as vitallium) but these results have not been conspicuously successful. The only method of assuring safety is early X-ray diagnosis and complete immobilization.

Fractures of the ribs are quite common and usually unimportant injuries and the vast majority of them heal without any particular treatment. However, compensation and legal considerations often require an answer as to whether or not a fracture is present in a given case of alleged chest injury. In at least 10 percent of actual fracture cases, the fracture line is not immediately demonstrable by ordinary X-ray methods. It is concealed by its obliquity or by overlapping parts. Therefore, your physician may tell you in such a case that there is "no X-ray evidence of fracture" rather than "there is no fracture." If it should be of legal importance to confirm a suspected fracture in such a case, reexamination at the end of 4 weeks' time usually will provide the answer. By that time a little "fuzz" of new bone will be present in the fracture site and will be visible in the roentgenograms.

Roentgen methods are also invaluable in the detection of various types of bone disease due to infection, tumor, and so forth. However, the shadows cast often are not characteristic of one particular infection. For example, a bone that has been disused for several weeks (perhaps in the foot, when a patient is wearing an extensive plaster splint for fracture of the upper leg) may cast a shadow identical with that of one extensively diseased. Therefore, it is necessary for the roentgenologist to have some of the clinical facts or history of a given case before rendering an interpretation of a film. The film is not misleading; our deductions, in the absence of clinical data, may be misleading.

Some diseases cause fairly characteristic changes in bone, but these are in the minority. The more experience the observer has the more he realizes that a host of different conditions can produce identical pathological and, therefore, identical radiological changes. A good example of this is leprosy. Many years ago an author reported "characteristic" atrophy of the terminal phalanges as a fairly early sign of this disease. On studying cases of nerve disease of other types, and of obliterative or spastic vascular diseases of various types, it was found that quite identical changes occurred in many of them. Phosphorus poisoning causes changes in the jaw bone similar to those of infection and of radium poisoning. Thus, it is important to maintain reserve in accepting reports of new or "characteristic" findings in disease.

One interesting finding in roentgenograms of children's extremities is that seen in lead poisoning. Children who have licked the paint off of their toys or pens sometimes develop signs of joint disease or leg weakness. If they have been following this dietary indiscretion for some time, the growing ends of long bones will show dense lines due to actual deposit of lead salts therein.

The roentgenologist is required to have a general knowledge of the development, anatomy, and pathology of the teeth. Satisfactory examination of the teeth requires careful technique and even more careful interpretation. Without the latter, early abscesses at the roots of the teeth, early areas of caries or decay in the crowns, and similar processes may be overlooked.

The value of a consultant specialist is almost nowhere better seen than in certain cases of dental radiography. The dentist or family doctor is apt to look at such films with his thoughts concentrated purely on the dental structures and innocently may neglect a malignant growth in the adjacent bony mandible, a lesion which an expert in the field of X-ray interpretation would be apt to detect readily. It is not suggested that ability in such interpretation is confined exclusively to the roentgenologist. Any person, professional or otherwise, can learn how to interpret films of certain parts of the body after a fairly short period of training. However, the human tendency is to concentrate on the matters in which one is most interested and to overlook other data, even though such are quite apparent on retrospect.

Normal joint cartilage casts no distinguishing shadow in roentgenograms so routine Roentgen methods are not of much value in the early diagnosis of many types of joint disease. However, "soft-tissue" films of joints, and films made following intra-articular injection of air do provide valuable diagnostic information in many cases. Roentgenograms are of considerable value in the differential diag-

nosis of established cases of joint disease (chronic rheumatism, gout, specific infection). Bleeding in and about joint areas, such as occurs in hemophiliacs, presents fairly characteristic changes.

Respiratory system.—If roentgenology had made no other contribution to medicine than the ability to study the shadows cast by the lungs in living individuals it would have performed a tremendous boon. But before considering this portion of the system, let us commence at the upper portion of the respiratory tract, namely the nose and nasal accessory sinuses. The cartilages, bones, and even the skin of the nose can be radiographed with simplicity, and various injuries and other conditions accurately diagnosed. The nasal accessory sinuses, nasal passages, and adjacent areas can be recorded and various conditions ranging from sinusitis to cancer detected. The air passages leading from the nose to the lungs can be portrayed and the true and false vocal cords may be studied both fluoroscopically and radiographically. A special technique known as body-section roentgenography (laminography or tomography) permits the obtaining of films of such areas as the cords relatively free from underlying or overlying shadows. In this method the tube and film are moved synchronously but in opposite directions about a fulcrum, the location of which depends on the height above the X-ray table of the area to be studied.

All types and varieties of diseases of the lungs and pleura are amenable to X-ray diagnosis, and many require such examination for their elucidation. Communicable diseases such as active lung tuberculosis provide an excellent example. In recent years the training of increased numbers of physicians in radiology plus the development of special X-ray apparatus has permitted mass surveys of hundreds of thousands of individuals. The best method involves the use of standard (14- by 17-inch) films. A slightly less expensive and currently popular method is the photofluorographic one, in which the fluoroscopic image is photographed on small or roll film (35-millimeter, 70-millimeter, or 100-millimeter widths, depending on the type of equipment). The film comes in rolls of from 35 to 100 frames, permitting a like number of exposures. Some of the newer units have built-in photoelectric cells by which the X-ray exposures are timed automatically. This strip film is processed in special developer, then dried and viewed either in a magnifying trans-illuminator or by means of a projection unit. The detail in the films is naturally not as great as in the conventional 14- by 17-inch film but it is sufficiently good to permit screening of lungs for significant lesions. The prime object in the method is to detect cases of open pulmonary tuberculosis, that is, patients with cavities or other lesions from which they cough bacilli and so innocently infect their fellow

citizens. Miniature films permit the detection of most such lesions. About 1 percent of apparently healthy adults are found to have some significant lung condition on such surveys, but fortunately only 1 in 400 has evidence of "open" disease.

The X-ray unit has not made the stethoscope obsolete but it has given the physician a weapon with which he may detect numerous diseases of the chest at a stage long before they could otherwise be discovered. In this manner they have been a major factor in saving countless lives and in preventing much advanced disease.

LOCALIZATION OF FOREIGN BODIES

X-rays are essential for the detection and accurate localization of most foreign bodies in the tissues. These bodies may be divided into two general types, nonopaque to the X-rays and opaque. Surprising as it seems, nonopaque foreign bodies frequently may be localized, with considerable accuracy, by careful examination. For example, a peanut lodged in one of the bronchial tubes will itself cast no shadow; however, it will produce partial or complete obstruction of the bronchus. As a result the involved lobe of the lung will show either persistent distention with air on expiration, or gradual collapse. Nonopaque foreign bodies in the alimentary tract often may be located by giving the patient small barium-soaked cotton pledgets or swallows of barium cream. Nonopaque foreign bodies in other parts of the body sometimes are located by injecting radiopaque liquids into draining sinus tracts.

Opaque foreign bodies, common in war time, may be found and localized by various methods. The simplest is by roentgenoscopic and roentgenographic examination in two planes at right angles to each other. Other methods include parallax and triangulation. The detection and localization of small metallic bodies in the eye may be performed with the aid of special apparatus. That most generally employed involves examining the patient's eye in accurate relationship to two fixed objects placed at a known distance from the cornea. The data obtained from two films made at different angles are transferred to a special ruled chart, and the position of the body indicated in three different planes with an accuracy of less than one millimeter.

Protection against unnecessary or excessive exposure to X or radium rays is one of the utmost importance for patient, operating personnel, and radiologist. Protection against excessive exposure from the direct beam is now well established in responsible offices and departments by methods which include careful calibration of the apparatus, adequate distance between tube and patient's skin, use of lead-protected shockproof tubes, suitable diaphragms, and filters.

Protection against radiation scattered from the patient or the X-ray

table is often more difficult but, unfortunately, sometimes is overlooked. The best way to achieve this protection is to use as small a beam as possible in examining patients, to work as expeditiously as is consistent with thoroughness, and to stay at the maximum distance or behind the safest barrier available. Protective barriers usually are made of lead or concrete. If workers are not safeguarded properly they may develop injury to the blood or reproductive system with consequent dangers of anemia, leukemia, or sterility. The tolerance dose is the total X-ray energy that a person may receive continuously without suffering damage to the blood or reproductive organs. For most workers it is set at 0.2 roentgen per day (a dosage rate not exceeding 10^{-5} per second). Detailed rules for protection are available in the National Bureau of Standards Handbooks 20 (X-ray protection) and 23 (Radium protection).

X-RAYS IN TREATMENT

X-rays are of considerable significance in the treatment of a large number of diseases, ranging from simple infections such as ringworm of the scalp to serious processes such as cancer. The physician performing Roentgen therapy must strive to be as careful in the calibration and handling of his apparatus as a physicist, and as accurate in the application of his rays as a surgeon is when applying his knife. The therapist has at his disposal a wide variety of equipment supplying low-voltage beams for superficial treatment (40 to 100 kilovolt), intermediate voltage for more deeply seated lesions (120 to 150 kilovolt), high voltage for deep-seated lesions (180 to 220 kilovolt) and, finally, extra-high voltage for a few selected conditions or for biological research (400 to 1,000 kilovolt). He must select a filter suited to the procedure desired, varying from less than 1 millimeter aluminum up to as much as 5 millimeters of copper. He calculates his dose in roentgens, and delivers small doses to most inflammatory or benign conditions, and very high doses to certain localized malignant lesions. A small dose ranges from 10 to 100 roentgens and may need to be repeated at intervals for weeks or even months. For example, generalized acne vulgaris may require weekly doses of 100 roentgens for three months. On the other hand a small localized cancer may require 6,000 roentgens delivered either at one session or, depending on the amount of associated infection and similar complications, in several sessions. The essential effect of X and gamma rays on the tissues is a destructive one. Cancer cells are slightly more sensitive to such radiations than are normal cells, and for this reason it is possible to destroy some cancers without permanent injury to the normal surrounding tissues.

The following is a partial list of conditions in which X or gamma rays are of value: Inflammatory diseases of the skin and adjacent

tissues; certain thickenings of the skin (plantar warts, keratoses); disturbed function of certain glands such as salivary and thyroid (hyperthyroidism); many benign and malignant tumor conditions.

Just as the mere possession of a knife does not make you a surgeon, so the possession of X-ray apparatus or radium does not make you a radiation therapist. The safe and efficient application of radiation methods in disease requires as much skill and even more training than many types of surgery. It also requires recognition of the fact that there are many conditions far better treated by nonradiological methods and a few which actually are rendered worse by Roentgen treatment.

The rays may be applied to human tissues by a variety of methods including external application of the beam, internal (intracavitary) application, interstitial application (that is, direct insertion of radium or radon seeds into the tissues), and various combinations of these methods, all designed to deliver the involved tissues a specific planned radiation dose.

FUTURE DEVELOPMENTS

The world has seen tremendous advances in the X-ray field during the past 50 years but there still are numerous developments, both in apparatus and technique, to which physicists and physicians are looking forward. These include the following:

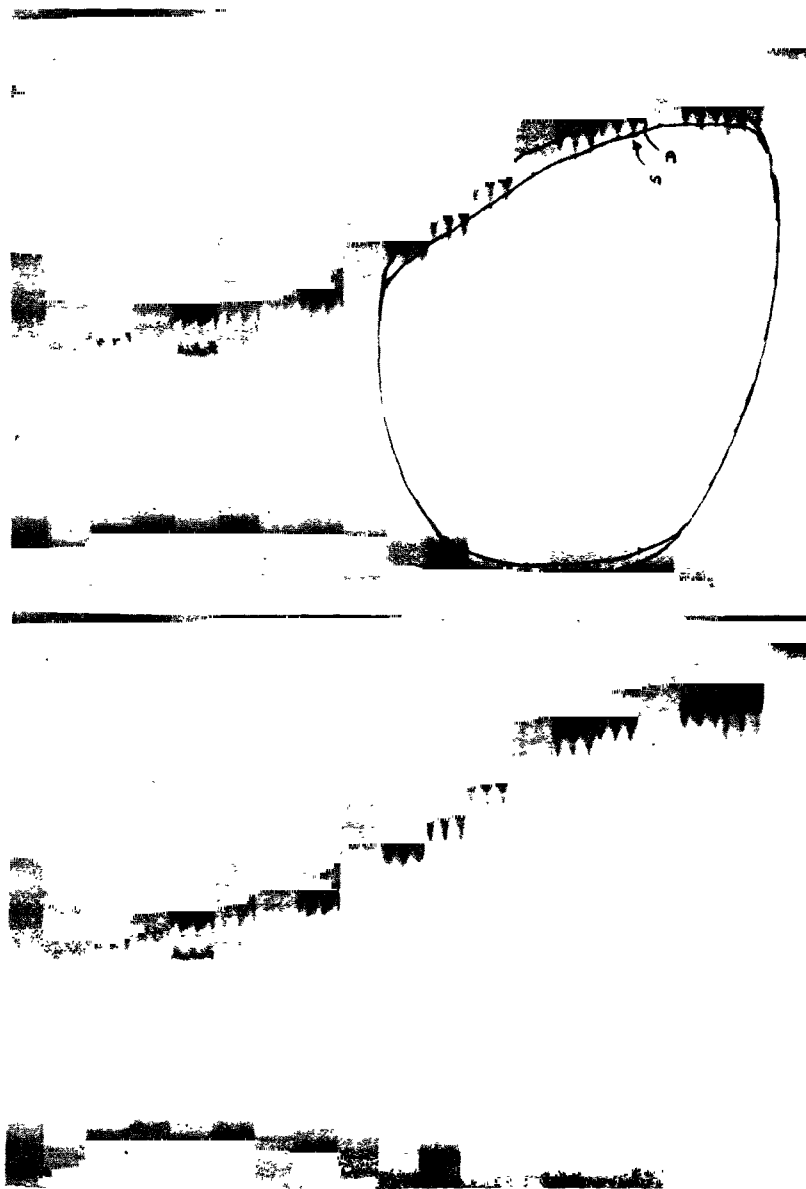
1. More efficient recording media, including improved film emulsions, processing equipment, and fluorescent screens.
2. Improved simplified exposure meters and automatic timers.
3. Finer focal-spot diagnostic tubes.
4. Greatly improved fluoroscopes, perhaps an electron fluoroscope, and, as a result, better, safer X-ray motion pictures.
5. More widespread use of X-rays in teaching and in preventive medicine (including the installation of X-ray units in morgues to aid in research and routine autopsy work).
6. Improved methods of calculating the size and depth of tumors, so that radiation beams may be still more accurately aimed.
7. Improved selection of patients for both diagnosis and treatment (to reduce unnecessary expense and unnecessary exposure of human tissues—especially the reproductive organs—to X or gamma rays).
8. Finally, and most important of all, the training of more and better radiologists, medical physicians specializing in X-ray diagnosis and treatment.

The value of X-rays to science in general and to medicine in particular is immense and ever increasing. They have provided us with a weapon by which we may search out the structure of matter, as well as the hidden components of the body. The diagnosis of innumerable disease conditions is dependent largely or entirely on X-ray examinations and the treatment of several types of disease likewise requires Roentgen irradiation. The debt of mankind to Roentgen and

his fellow workers in the field of physics and engineering cannot be repaid easily.

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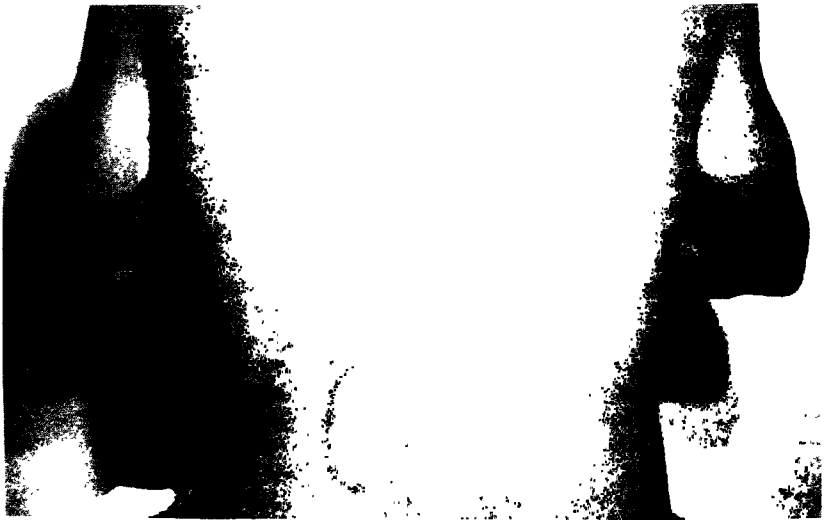
ROENTGENKYMOTOGRAPH OF THE HEART OF AN ADULT MALE

- 1 Three contractions of the heart are visible in each of the frames with the tip of peak of each wedge representing maximum expansion and the base of each maximum contraction of the heart dilated and systolic in position. The contractions are of 10 and 100 and 1000 mm. (Exposure time, 2 seconds).
- 2 Same case as figure 1, illustrating method of tracing the outline of the heart at slow in contraction (s) and expansion (d). In this way the outline of the heart is ascertained.



1 LEFT WRIST OF ADULT MALE SHOWING FAINT FRACTURE LINE IN ONE OF THE SMALL BONES (THE SCAPHOID).

Fracture is indicated by arrow



2 LOCALIZED BLEACHING OF THE SKIN OF THE LOWER BACK OF AN ADULT MALE AS A RESULT OF EXCESSIVE ROENTGEN IRRADIATION (HEALED X-RAY BURN)

Oval area of pallor surrounded by brown pigmentation is the effect of a second-degree burn suffered some months before when the patient underwent X-ray examination of his stomach by an untrained worker

VISIBLE PATTERNS OF SOUND¹

BY RALPH K. POTTER
Bell Telephone Laboratories

[With 4 plates]

The automatic representation of speech sounds by visible traces or symbols has long been a subject of interest to acousticians and phoneticians, and especially to those concerned with the development of electrical communication. Techniques for automatically recording the wave forms of sounds have been very highly developed; but there has remained unsolved, until recently, the problem of recording sounds in a manner permitting their ready visual interpretation and correlation with the auditory sense. An outstanding difficulty with the interpretation of the records of wave forms is the effect of phase relationships between fundamental and harmonics. These effects may produce a marked difference in the appearance of the wave forms of two sounds that are quite indistinguishable to the ear. Consequently, wave traces of even simple vowel sounds do not permit of easy identification by the eye.

The facts are that wave traces contain too much information. To portray sound in a form that the eye can encompass in a glance requires that some means be provided for selecting the essential information and displaying it in an orderly fashion. A form of display that meets these requirements has been developed in the Bell Telephone Laboratories as described below.

The work here described was begun before the war. Because of related war interests it was given official rating as a war project, and has progressed far enough during the war period to justify its being brought now to public attention.

The possible uses of an automatic system for translating sound into patterns which may be readily interpreted by the eye are very numerous. It opens the prospect of some day enabling totally deaf or severely deafened persons to use the telephone and the radio or to carry on direct conversation by visual hearing. (The latter, in-

¹ Bell Telephone System Technical Publications, Monograph B-1368, Acoustics. Reprinted by permission from Science, vol. 102, November 9, 1945.

cidentally, was an objective of the early researches of Alexander Graham Bell.) It suggests the possibility of printing words phonetically and of the automatic retranslation of such printed symbols into understandable sound. It opens the way to the selective operation of automatic devices by voice sounds. It promises to be particularly useful in the specialized fields of phonetics, philology, and music. But most immediately, and from humane considerations most importantly, it opens a new avenue of help to the totally and severely deafened—help to learn to speak, and for those who already speak, help to improve their speech. It is to this problem of aid to the deaf that we have first directed our efforts.

It is too early to evaluate the results of these efforts with certainty. That there is a firm basis underlying the legibility of the visible speech patterns which have been obtained can hardly be doubted, but many questions remain concerning the design of practical translating equipment, the time and effort necessary to acquire a reading vocabulary, the effects of transmission and reception conditions on pattern legibility, and the special needs of the equipment for speech teaching and rehabilitation. These questions cannot and should not be answered hastily, even though they are naturally urgent to those afflicted with a serious hearing loss. Their answering requires, during the developmental stages of the equipment, the cooperative efforts of the engineer and the groups concerned with the problems of deafness. The purpose of the present paper is to introduce the subject of visible patterns of sound and to describe briefly some of the more general aspects of the work with them.

In plate 1 are shown two forms of the new sound patterns. Both represent the same words—"This is visible speech"—and both show the three basic dimensions of sound—frequency, time, and intensity. It should be noted that the words associated with the different sections of the pattern, are inserted at the top of the figure. Time extends horizontally, the total length of each record being roughly $2\frac{1}{2}$ seconds. Frequency is spread out vertically from substantially zero at the bottom of each record to about 3,500 cycles at the top. Intensity is shown by the varying shades of gray. Resolution of the frequency dimension is the significant difference between this and other more familiar displays of sound such as the oscillogram. Such a display provides for the eye the frequency analysis which is natural in aural perception and necessary for an understanding of sounds.

Patterns of the type illustrated by plate 1 (*a*) are of interest in studies of speech characteristics, while the type shown in plate 1 (*b*) are of interest in visual hearing and phonetics. The former pattern shows the frequency composition in great detail, so that the individual harmonics of voiced sounds may be seen, and the manner in which

the frequency of the harmonics varies with time. Patterns of the second type show only the broad frequency and time distribution of energy resulting from selective modulation. It is such modulation, produced by variations in the voice cavities accompanying the formation of word sounds, that conveys the information in speech. Incidentally, the vertical striations appearing in plate 1 (*b*) are produced by beats between adjacent harmonics so that in the voiced parts their density or frequency of occurrence is a measure of pitch, increasing as the pitch increases.

The patterns of plate 1 and others described later were made by an instrument that we have called the sound spectrograph. In this instrument, the sound to be pictured is recorded initially on a loop of magnetic tape and played back repeatedly into a scanning filter, the pass band of which is moved slowly across the frequency spectrum. The scanning filter output is connected to a stylus that makes a trace upon a loop of electrically sensitive paper. Recording paper and magnetic tape loops are moved in a fixed relation so that successive scanning cycles are recorded side by side, thus building up a frequency-time-intensity picture.

If the words pictured in plate 1 were repeated at different times by the same speaker, the repetitions would look much alike unless a deliberate attempt were made to change the voice. If the words were spoken by different individuals they would also have a similar appearance, although the pattern shapes would vary with individual characteristics in much the same way that handwriting varies among individuals. To the extent that words sound alike they will also look alike in visible speech form, and to the extent that they sound different they will look different. That is, of course, to be expected if the portrayal is accurate.

The similarity in word patterns for various individuals is illustrated by plate 2. Here are shown six enunciations of the word "speech" by as many speakers. As indicated, the upper three are female voices and the lower three male. The brief descriptions at the right are only intended to give an impression of the wide range of voice quality represented and should not be interpreted as meaning that all speakers with a "throaty voice" or a "Scotch-Irish accent" or an "English accent" would produce patterns that are just like those so identified. The important point in this illustration is the evidence that characteristic differences in pronunciation do not overshadow the similarities that enable one to recognize particular words. Such similarities illustrate the possibilities of these patterns for visual hearing.

In the studies of sound patterns as applied to the problems of the deaf, the objective thus far has been to determine whether the pat-

terns are sufficiently intelligible for practical use. This has involved a careful study of the patterns of different sounds and sound combinations with respect to both their similarities and their differences. Two methods of investigation were utilized—the first by training individuals to read patterns and following their progress, and the second by what are called “visual discrimination tests” that require no training.

The training group formed for the purpose of learning to read the patterns originally included six girls with normal hearing. This group was assigned to the work on a part-time basis during the summer of 1943. Teachers were selected with experience in the fields of phonetics and education of the severely deafened, but they started the instruction with no previous knowledge of the speech patterns. In addition to this handicap, the first months of training were based entirely upon the sound spectrograph patterns which require several minutes for completion.

A method of instantaneous translation was needed badly, but equipment of this type was not available for class use until the fall of 1944. The first director translator utilizing a new form of moving screen cathode-ray tube was entirely too large and complicated for any but experimental instruction use. There has since been constructed a much smaller translator, approximately the size of a portable typewriter, with the speech patterns displayed on a moving drum of phosphorescent material. While this more recent unit approaches a practical size, it is still very much in the experimental stage and far from a finished design.

There is also under experimental development a large screen translator of the same general design as the small unit but using a belt of phosphorescent material in place of the drum. In all three of these translators, transient speech patterns are formed by tracing on a moving screen the frequency distribution of speech energy as determined by a bank of fixed band pass filters. The frequency scale used for the speech patterns is linear, although patterns with other scales, including the logarithmic type, have been produced.

One objective in the development of a small translator is to provide an instrument that might ultimately be associated with telephones in such a way as to permit the very deaf to carry on telephone conversations by seeing, rather than hearing, the speech signals.

Due, at least in large part, to the exploratory nature of the training program and the time required to develop adequate equipment, the ability of the experimental class to read visible speech increased at what would be considered a slow rate for learning lip reading, shorthand, or foreign languages. However, the learning rate improved considerably as the training methods and translators were improved. Recently a congenitally deaf engineer, who depends entirely upon lip

reading, has been added to the class. His learning rate for visible speech has so far compared favorably with that for lip reading. During his training he has been tested regularly on his ability to read word patterns in the visible speech form and by reading lips. Although adept at lip reading, and the lip-reading tests were carried on under exceptionally favorable conditions, his score on reading visible speech has stayed well above that for reading lips. Incidentally, his is probably the first case in which a person with substantially no hearing has been enabled to talk over an ordinary telephone circuit without the aid of a human "interpreter."

Thus far the results of the experimental training encourage confidence that these speech patterns may provide a practical form of directly translated visible speech, but much more training experience is needed for complete confirmation.

A second way to determine the legibility of word patterns, by means of so-called visual discrimination tests, was initially devised to get around a difficulty. It had been assumed at the start of the visual hearing project that the trainees would, after a period of training, be able to say whether one pattern presentation was better than another, and how the many variables that appear in the translator design should be treated. But this assumption proved to be mistaken. After training with one form of pattern there was a tendency to dislike others. It soon became obvious that an unbiased evaluation method was necessary as a guide to development.

The visual discrimination tests produced to meet this situation depend upon an assumption that any language, aural or visible, is made up of many patterns; and that the relative merit of different languages or of different representations of a single language depends upon the ease with which patterns that make up equivalent vocabularies may be identified. In the visible-speech case, one test method is to select words that in certain respect look alike, and arrange them in what are called "similarity series." Examples are, "man, ran, van, tan," etc. The words are spoken in groups of three, such as "van-tan-tan" or "van-van-tan." An observer of the patterns produced by these words is simply asked to check whether the middle pattern is more nearly like the first or last in a group. It is not required that the observer have any knowledge of the meaning of the patterns. Ratings are in terms of the percentage of correct pattern identifications, taking into account the fact that 50 percent accuracy represents pure guesswork. The figure so derived is called the "discrimination index." Poor patterns result in a low DI, or if the translator fails to show certain sounds clearly, the DI for word groups containing these sounds will be relatively low. Figures of this kind permit a quantitative appraisal of the performance of different translators.

Anyone who considers carefully the relation between aural and visual perception is likely to question the need for using a three-dimensional form of pattern for visible speech. The ear hears two-dimensionally in frequency and intensity. The time dimension is supplied by the memory. Why not then show only a frequency-intensity speech pattern and make similar use of the visual memory? The question is a perfectly valid one and has received considerable thought during the investigation under discussion. In fact, an experimental study of two-dimensional patterns is being carried on simultaneously with the three-dimensional studies. At the present time it is confined to visual discrimination tests of various two-dimensional displays. Earlier, one girl studied a particular form of pattern for a few months, but when the discrimination test methods were developed this training was discontinued in order to concentrate the available effort upon the more fundamental aspects of two-dimensional display.

Both the limited training and the visual discrimination tests made so far seem to indicate that it will be more difficult to read the two-dimensional patterns than it is to read the three-dimensional type. Three-dimensional speech patterns are analogous to print moving from right to left on a telegraph tape, while two-dimensional patterns are analogous to seeing this moving print through a narrow slit, only as wide as the lines that form the letters. No doubt we could learn to read print moving past such a narrow slit, but it would rather obviously be more difficult than unrestricted reading because we normally perceive whole words rather than bits of letters. It may well be that this manner of reading is a result of the requirement that the eye be focused upon the print in order to obtain a satisfactory memory impression. Although the focusing requires visual effort, large pattern areas may be recorded in a single "exposure" so that the effort is not excessive. But to record patterns a bit at a time, or two-dimensionally, by the visual process would require almost continual concentration and should therefore exact more effort for the same accomplishment.

It is possible then even though the eye should in theory be able to understand two-dimensional patterns of speech it may be inefficient for this purpose.

In addition to the problem of understanding others, deaf and severely deafened persons are faced with the problem of controlling their own speech. Making sounds without ears to hear them is somewhat like drawing pictures with no eyes to see the results. When the hearing is largely absent in a child, it is necessary to teach speech without normal control exercised by the hearing. Even in cases where a vocabulary is developed before severe loss of hearing sets in, there is a gradual deterioration of the speech. In both cases visible speech in the forms described here should be of considerable help in speech

training and rehabilitation. This has proven true in the case of the congenitally deaf engineer noted above. During the past year his speech has improved considerably and can be understood quite well by the average person with whom he comes in contact. His work with the translator patterns, however, has emphasized the desirability of providing an indication of the voice pitch.

Unless the acoustically handicapped are able to control the pitch and the volume of the voice as well as the positions of the articulators, their speech will sound unnatural although it may be intelligible. The best ways to display pitch are still uncertain. One possibility is by means of a wave trace perhaps below the pattern; another by a fixed trace, in which the line intensity is varied in proportion to the fundamental frequency. The latter is simpler from an apparatus standpoint, but in a first experimental use seemed less acceptable as an indication.

There remains to be discussed potential uses for these sound patterns in various fields of specialized acoustics for purposes of analysis and illustration. The foregoing discussion of speech patterns indicates in a general way the possibilities as applied to phonetics, philology, and speech correction and development, but the patterns have many uses for the visual interpretation of complex waves other than speech. Plates 3 and 4 include a number of pictures of more or less familiar sounds that may illustrate better than speech the relationship between what we hear and what we would see in this form of visible interpretation. Sustained tones produce horizontal lines as in A of plate 3. The clicks of a hammer against a metal block contain brief spurts of energy spread over the whole frequency range, so that they appear as vertical lines in B of plate 3. Swinging the frequency of a variable oscillator up and down the scale results in the wavy line of C in the same figure.

The remaining patterns of plate 3 and those of plate 4 are described fairly well by the brief captions. For those interested in a more detailed examination of the time and frequency dimensions it should be added that in plate 3 (A to G inclusive and I and J) and in plate 4 (E to H inclusive) the length is approximately 9.4 seconds and the vertical scale includes a frequency range of zero (at the black base line) to 3,200 cycles per second at the top. In H of plate 3 and in the first four patterns of plate 4 (A to D inclusive) the length is approximately 4 seconds and the frequency scale is zero to 7,500 cycles per second.

The bird songs² pictured in plate 4 were originally selected for use as test material because they contain a wide variety of tone modula-

² These sound spectrograms were made from the Cornell Bird Song Records (Albert R. Brand Bird Song Foundation, Laboratory of Ornithology, Cornell University).

tion without the complications appearing in sounds that are rich in harmonics. But these song patterns are obviously revealing and illustrate well the possibilities of sound portrayal. With such patterns as these it will be possible to analyze, compare, and classify the songs of birds, and, of even more importance, it will be possible to write about such studies with meaningful sound pictures that should enable others to understand the results. The same argument applies to an almost endless variety of inaudible as well as audible sounds of both natural and mechanical origin. Even such low-frequency oscillations as those accompanying the beat of the heart may be recorded slowly and converted to the sound spectrogram form by high-speed reproduction. Also frequencies beyond the upper range of the ear may be shifted to the audible range by well-known methods so that sound spectrograms may be made in a region where recording is less difficult.

In conclusion, it is well to point out that this is necessarily an incomplete story of the sound portrayal development. Nothing has been said about several important points: for example, use of a logarithmic frequency scale, and a frequency selection that corresponds more closely to the aural experience; and better amplitude representation by contours, color, and other means. Some interesting results have been obtained in developments along these lines but it seems best to reserve them for later discussion. Also, a great deal could be said about the need for a modernized alphabet in this age of speed when a rapid exchange of ideas and information is increasingly important, but this too had better be reserved for some later occasion.

Many members of the Bell Telephone Laboratories, including both engineers and those associated with the experimental training, have cooperated in this development work. All have displayed an enthusiastic interest and it is a pleasure to acknowledge their contributions.

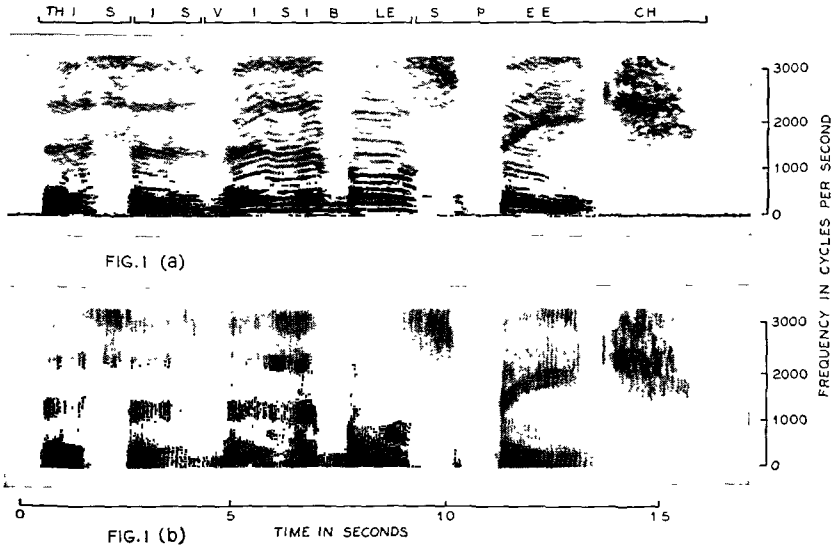
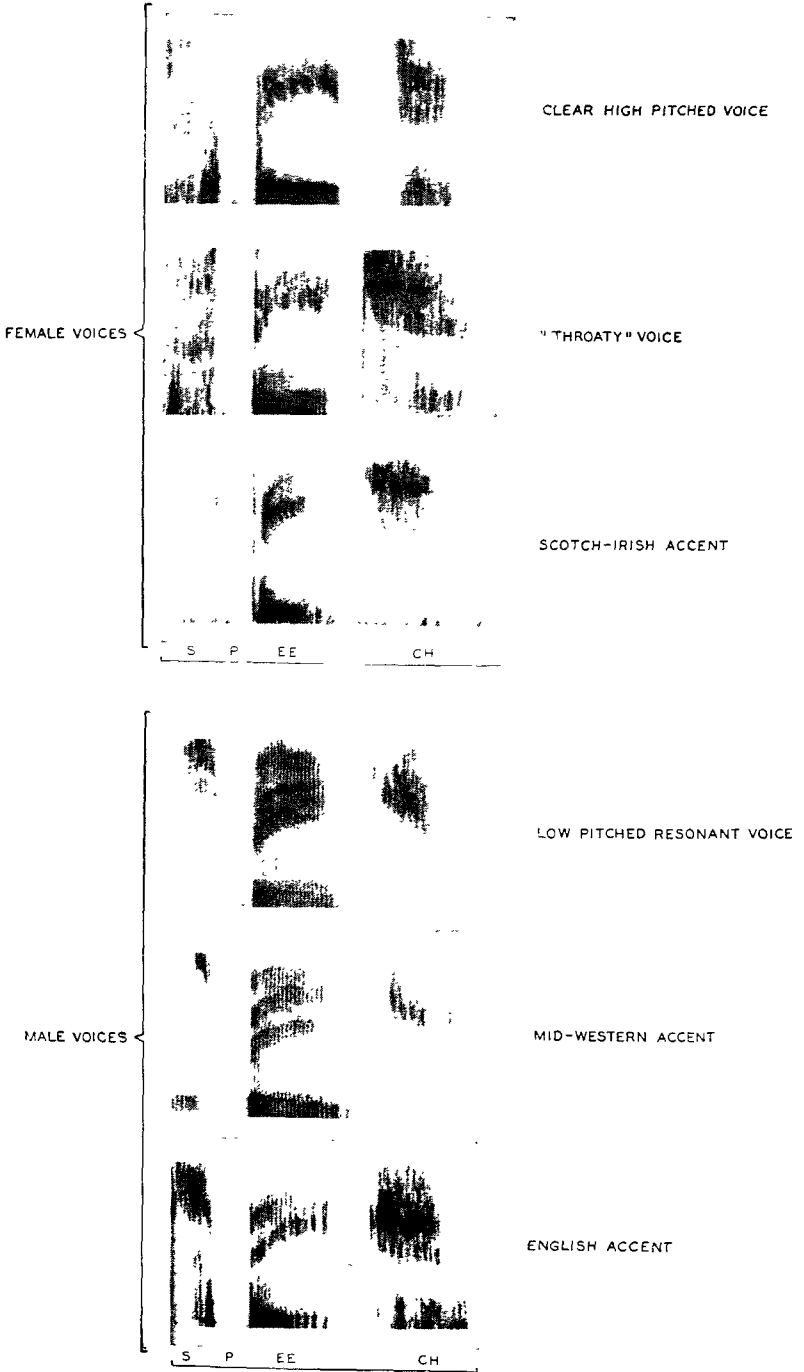
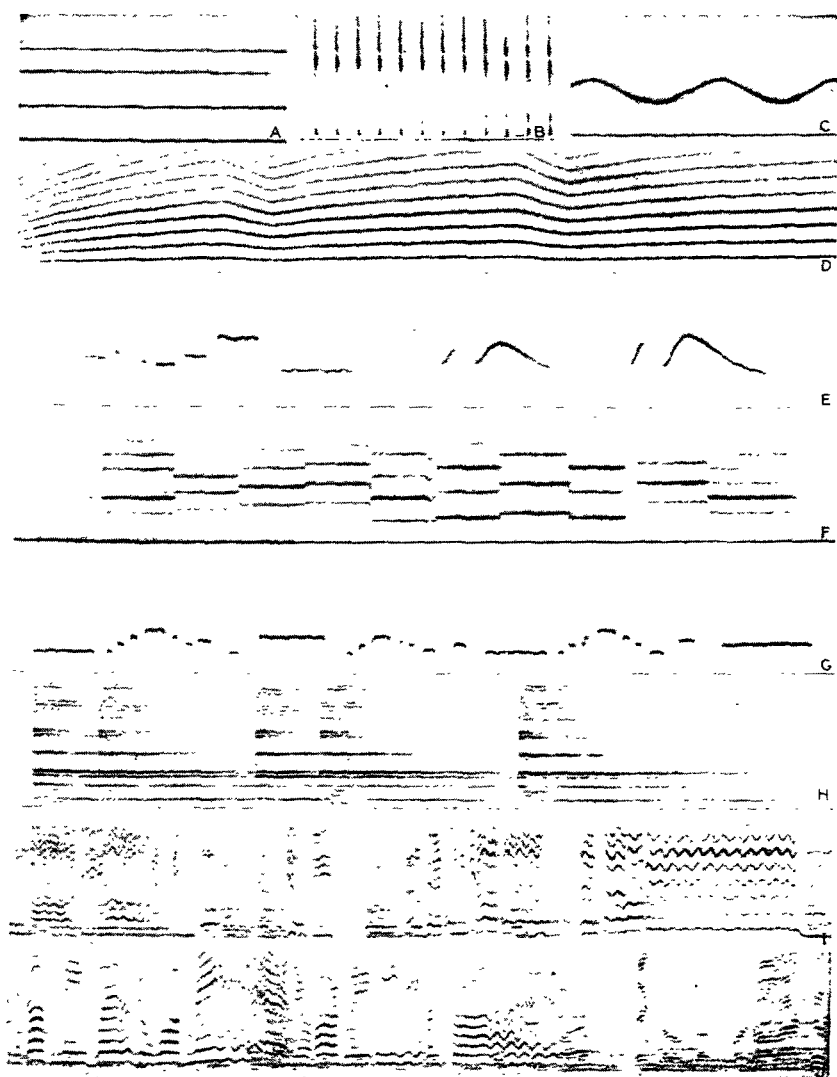


FIG. 1 (a).--High-detail sound spectrogram of the words "This is visible speech," showing the darker regions of mouth cavity resonance superimposed upon the detail of harmonics in voiced sounds.

FIG. 1 (b).--Low-detail sound spectrogram of the same words, showing the resonant regions as dark bands and eliminating detail.



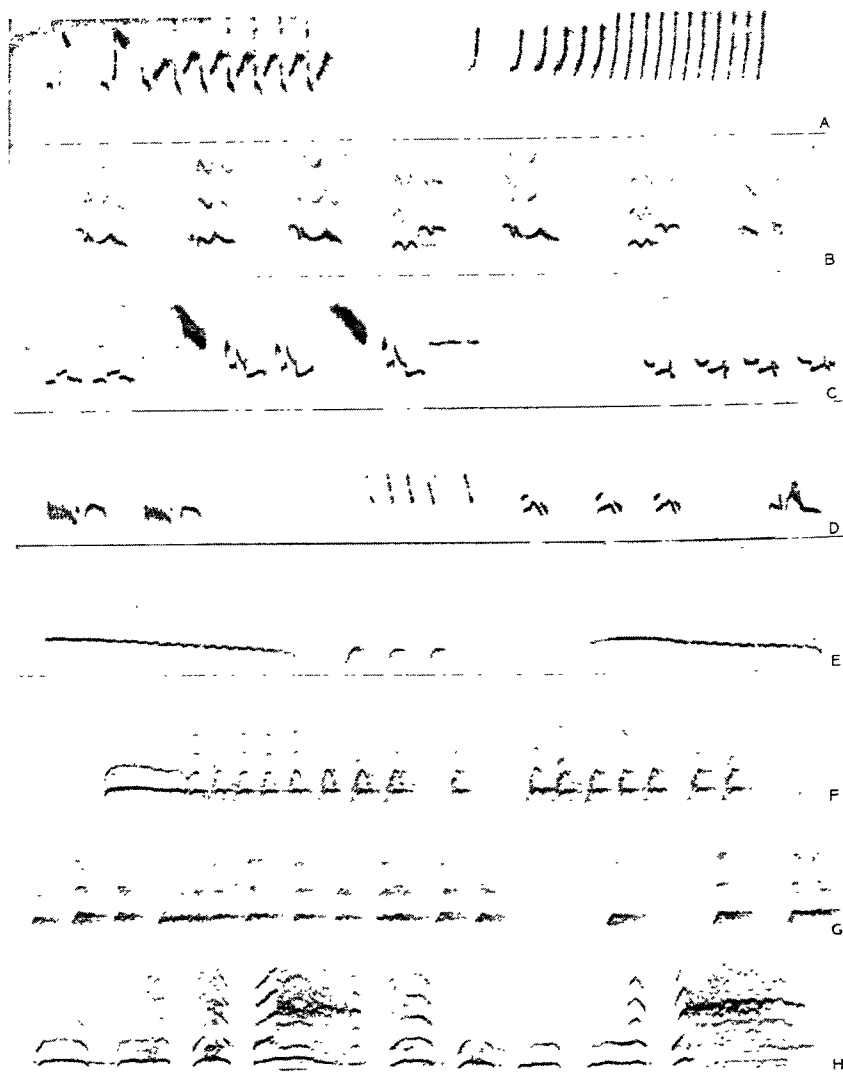
Patterns of the word "speech" by six different speakers, including male and female voices and a wide range of pronunciation.



A, three steady tones
B, hammer clicks
C, wobbled tone

Sound patterns of:
D, *siren*
I, man whistling
F, oboe solo
J, soprano and baritone

G, ocarina solo
H, ship's bell and bells
I, tenor and orchestra



Sound patterns of.

A, cardinal

C, mocking bird

E, screech owl

G, small dog yapping

B, robin

D, brown thrasher

F, large dog barking

H, baby crying

FLUORINE IN UNITED STATES WATER SUPPLIES¹

PILOT PROJECT FOR THE ATLAS OF DISEASES

BY ANASTASIA VAN BURKALOW

[With 1 plate (map)]

Within the last 15 years attention has been increasingly directed to the distribution of fluorine in the water supplies² of the United States; for it has been demonstrated that a small amount of fluorine, about 1 part per million, is necessary for optimal dental health. Where the fluorine content of the drinking water is much less than this, the dental-caries experience rates are high; where it is greater, the disfigurement known as dental fluorosis or mottled enamel is endemic.³

Because of this direct relationship between dental health and an element of the physical environment, the water supply, a study of the problem was chosen as the pilot project for the American Geographical Society's proposed Atlas of Diseases,⁴ the primary purpose of which is to show the correlation of disease with the natural and social environment. The growing public interest in the effects of an excess or deficiency of fluorine on the teeth, and the many studies of the problem made in recent years contributed to the choice of this project as the first to be undertaken.⁵ Dr. H. Trendley Dean, senior dental surgeon, United States Public Health Service, who has done outstanding work in this field, has kindly served as consultant for the investigation, the purpose of which is to determine the distribution of fluorine in the water supplies of the United States as far as it is now known and to show where possible the correlation

¹ Reprinted by permission from *The Geographical Review*, vol. 36, No. 2, April 1946.

² The fluorine in water supplies is, of course, in combined form, most of it probably as calcium or sodium fluoride. In the analyses, however, amounts are expressed in terms of uncombined fluorine.

³ For a review of the studies that have led to these conclusions see F. S. McKay, H. Trendley Dean, et al., *Fluorine in dental public health: a symposium*, New York Institute of Clinical Oral Pathology, New York, 1945.

⁴ *Geogr. Rev.*, vol. 34, pp. 642-652, 1944.

⁵ This decision was made by the Steering Committee for the Proposed Atlas of Diseases, at its meeting at the house of the Society on Sept. 22, 1944. During the rest of 1944 preliminary correspondence with the State sanitary engineers was carried on by the Director of the Society, Dr. John K. Wright. In January 1945, work on the project was assigned to a research assistant, Mrs. Luella N. Dambaugh. Upon her resignation in August of that year, she was succeeded by the writer.

between the fluorine content of the waters and the water-bearing layers from which they are derived.

This paper is a presentation, not of final conclusions, but rather of the methods of research used and of some of the problems met with in carrying on the study, and of the results reached so far.

COLLECTING THE DATA

The first step in collecting data on fluorine in the water supplies of the United States was the sending of a form letter to the Sanitary Engineer of each of the 48 States and of the District of Columbia. With the aid of a reprint from the *Geographical Review*^{*} the plans for an Atlas of Diseases were presented, and information was requested on the presence of fluorine in the waters of the State, on literature dealing with the matter, and on agencies from which further information might be obtained.

Within a reasonably short time replies had been received from all but two States. A few of these replies merely stated that no data were available. Most of them, however, furnished concrete information, sometimes much, sometimes little, but always helpful. This included material of the following types:

1. Tabulations of statistics, both published and unpublished.
2. Reprints and maps.
3. References to publications.
4. Names of individuals, firms, and public agencies from which additional information might be obtained.
5. Personal statements, some detailed, some general, about the presence or absence of fluorine in the water supplies of the State.

For half a dozen States the answer was that data such as we wanted were in process of tabulation and would be sent as soon as available. Some of this material has not yet been received.

Letters were then written to all persons and agencies referred to in the answers to the first form letter. These brought similar types of replies.

The enthusiastic responses from the sanitary engineers to whom we first wrote and from the health officers, State geologists, and others to whom they referred us are deeply appreciated. Many of these men went to considerable trouble to assemble statistics and compile maps for our use. Some of them have written more than once, and practically all have expressed interest in the project and a desire to help in any further way possible. Without such wholehearted cooperation it would have been impossible to accomplish as much as has been done.

The next step was, of course, a study of the literature on the subject, the references being acquired from the above correspondence, from indexes, and from cross references.

^{*} Op. cit. (see footnote 4).

At the suggestion of W. D. Collins, chemist in charge, Quality of Water Division, United States Geological Survey, a visit was made to the Washington office of the Survey, where access was kindly granted to the files of unpublished water analyses. About 1,500 additional analyses were derived from this source.

MAP SUMMARY OF QUANTITY OF AVAILABLE DATA

These sources yielded some 12,000 analyses showing the fluorine content of water supplies. As a preliminary to the preparation of a fluorine map of the United States it was desirable to see how the data were distributed. For this purpose a map (A on pl. 1) was prepared showing in a general way the amount of information available for each county in the country. A distinction was drawn between the counties for which five analyses or more were available, those for which one to four analyses were available, and those for which no analyses were available. A few areas were shown as being covered by a "general statement." This means that, although our collection does not include any analyses from these areas, some have been made, and on the basis of them a public-health or sanitary officer has given a general statement about the fluorine content of the waters.

This arbitrary classification of the abundance of data in terms of number of analyses per county does not take into consideration the sizes of the counties, which differ greatly, and therefore does not give a true picture of the number of analyses in proportion to area. Five analyses represent the conditions in one of the large western counties less truly than in a small eastern county. Nevertheless, the map does reveal the relative amount of attention that has been given to the problem in different parts of the country. The areas most thoroughly studied are the Great Plains and the Southwest. Comparison with C and D on plate 1 shows that these are the areas where the problem of excessive fluorine is most widespread.

Apparently public interest has been aroused, and health officers have been stirred to action, more widely by the dangers of fluorine excesses than by those of fluorine deficiencies. This interpretation is supported by several circumstances. Although a relationship between fluorine and dental caries was suggested at least half a century ago,⁷ no attention was given to the fluorine content of water supplies until 1932, after a high content had been definitely identified as the cause of mottled enamel.⁸ From that time on, and beginning in the States most afflicted with the malady, recognition of the importance of fluorine

⁷ Dean, H. Trendley, Domestic water and dental caries, *Journ. Amer. Water Works Assoc.*, vol. 35, pp. 1161-1186, 1943.

⁸ Churchill, H. V., Occurrence of fluorides in some waters of the United States, *Ind. and Eng. Chem.*, vol. 23, pp. 996-998, 1931; Smith, M. C., Lantz, E. M., and Smith, H. V., The cause of mottled enamel, a defect of human teeth, *Univ. Arizona Agr. Exp. Stat. Techn. Bull.* No. 32, 1931, reprinted 1937; and many later papers.

spread rapidly, and it began to appear in water analyses. Because the early emphasis was entirely on the problem of mottled enamel, small amounts of fluorine were at first considered of no significance. A few of the answers to our inquiries stated that no tests for fluorine had been made because the area had no problem of mottled enamel. The areas covered by the "general statements" are areas of low fluorine content, and a general statement to that effect was considered sufficient, whereas when the fluorine content was high, the exact amounts were almost always given.

It should be pointed out here that partly because of this thought pattern, emphasizing the importance of large amounts of fluorine, and partly because the early methods of analysis were not sufficiently refined, the early analyses showing small amounts of fluorine must be used with caution. They may sometimes err by as much as 0.4 or 0.5 p. p. m.⁹

This emphasis on the problem of mottled enamel is understandable for several reasons. Mottled enamel is a positive disfigurement, a definite abnormality endemic in certain specific regions. Dental caries, on the other hand, is usually much less obvious in its effects on personal appearance and is so much more widespread that it is almost taken for granted as a normal condition. Mottled enamel is attributable solely to excesses of fluorine, a relationship which was discovered in 1931. Dental caries can be attributed only in part to deficiencies of fluorine. It was first actually demonstrated in 1937 and 1938, by studies of the chemical composition of sound and carious teeth and by epidemiological studies of children in cities using water of different fluorine concentrations.¹⁰

In the number of people affected, there is no doubt that dental caries is a much vaster problem than mottled enamel. It is to be hoped, therefore, that there will be a more general recognition of the importance of knowing the exact amount of fluorine in our water supplies, whether it is much or little. It is only fair, however, to point out that such recognition is already more widespread than might appear from the map. In a number of areas where no fluorine tests have yet been made the reason has not been failure to realize the need but a lack of trained workers and equipment brought about by the war.

⁹ Personal communication from Dr. H. Trendley Dean.

¹⁰ Armstrong, W. D., Fluorine content of enamel and dentine of sound and carious teeth, Journ. Biol. Chem., vol. 119, proc. 5, 1937; Armstrong, W. D., and Brekhuis, P. J., Possible relationship between the fluorine content of enamel and resistance to dental caries, Journ. Dental Res., vol. 17, pp. 393-399, 1938; Dean, H. Trendley, Endemic fluorosis and its relation to dental caries, Publ. Health Repts., U. S. Public Health Service, vol. 53, pp. 1443-1452, 1938; Dean, H. Trendley, Jay, Philip, et al., Domestic water and dental caries, including certain epidemiological aspects of oral *Lactobacillus acidophilus*, *ibid.*, vol. 54, pp. 862-888, 1939.

CLASSIFICATION OF WATER SUPPLIES IN TERMS OF USE

Many of the analyses included on the map just described are of the waters of private wells, used by an unknown but usually small number of people or for irrigation, stock, and so on. If the data assembled by this study are to be of maximum value in studies of endemic dental fluorosis and dental caries, it is important to know how many people use a given water supply for drinking. For this reason Dr. Dean suggested that the water supplies represented on the first map be classified in terms of the use to which they are put. For this purpose two main types of water supply may be distinguished, communal and noncommunal.

Communal water supplies are those used as sources of drinking water by a large part or all of a community. They include supplies with such labels as "water companies" and "public," "municipal," "town," or "city" waterworks. For epidemiological studies these will be the most useful, since it is possible to ascertain approximately how many people use them. The emphasis is on use rather than ownership. Sometimes the communal water supply comes from a well or spring owned by a private individual. On the other hand, some publicly owned wells are used only for industrial purposes. Such would not be classed as communal.

Water supplies listed as "noncommunal" comprise privately owned wells and springs used for domestic purposes by one or two families, school and prison wells, and wells owned either publicly or privately but used for such purposes as irrigation, stock, industry, swimming pools, fishponds, and parks.

When the use to which a water supply is put is not clear, it is classified as "unidentified."

All the water supplies for which fluorine analyses are available have been classified in this way. The distribution of the resulting three types, communal, noncommunal, and unidentified, is shown in B on plate 1.

MAPPING THE FLUORINE CONTENT

As was mentioned above, inclusion of a fluorine test in water analysis is a recent development (1932 on) and has not yet become universal. This means that all earlier analyses and many of the more recent ones make no mention of fluorine. Incompleteness of data is therefore one of the major problems to be faced in making a map of the fluorine content of United States water supplies. Plate 1, A, shows that for many counties, sometimes for most of a State, no information is available. For many other counties there are available fewer than five water analyses that include a fluorine test. Analyses of many more water supplies are needed before a complete map of the country will be possible.

In most cases, also, more analyses of the individual water supplies are needed. It is well known that the fluorine concentration of waters fluctuates during the year, the maximum value often being several times as great as the minimum. This is true especially for surface supplies but also to a lower degree for ground-water supplies. For epidemiological studies it is the average value for the year that will be of greatest significance. Most of the fluorine analyses now available, however, represent single samples taken at random times throughout the year. Some of them may deviate from the average value enough to be misleading.

A different problem is introduced by the marked local variations in the factor to be mapped. The fluorine content of water depends largely on the nature of the rocks through which or over which the water has passed. Wells only a few feet apart may differ greatly in the fluorine content of their water because they were drilled to different depths and obtain their water from different aquifers. Supplies nearby may be obtained from surface waters, with a still different fluorine content. Experiment with a limited area, North and South Dakota (fig. 1), has shown that the mapping of all available fluorine analyses is impracticable except for detailed local studies. The variation within short distances is so great that the regional pattern of distribution is blurred, and the construction of isolines is impossible. Representation of the individual analyses by point symbols, the only alternative, presents a confusing picture and requires a large-scale map. A complete representation of the distribution of fluorine in water supplies would have to be three-dimensional.

As a solution to this problem, Dr. Wright suggested that only the maximum fluorine content known for each county be mapped. Figures 2 and 3 show the results for North and South Dakota, the first for all water supplies that have been analyzed for fluorine, the second for communal supplies only. On these maps a regional pattern of distribution of fluorine is revealed, and isolines have been drawn for the values 0.5, 1.0, and 1.5 p. p. m. These degrees of concentration were suggested by Dr. Dean as being of greatest significance as regards dental health. The highest dental-caries experience rates are associated with fluorine concentrations of 0.0 to 0.4 p. p. m. Resistance to dental caries is noticeably greater when the concentrations are 0.5 to 0.9 p. p. m. and reaches its maximum at concentrations of 1.0 to 1.4 p. p. m. With the latter values there is a very slight development of mottled enamel in a small percentage of the population, and higher values cause increasing development of this malady.

For the country as a whole the lack of information for large areas precludes the drawing of isolines. In plate 1, C and D, therefore, color is used to represent the known maximum fluorine content of water

supplies in each county, in terms of the same four degrees of concentration.

Several defects are inherent in this method of mapping. First of all, because of the incompleteness of the data, the maximum fluorine concentration on record for a county may not be the maximum value that really exists there. In a county represented on the map as having a maximum fluorine concentration in the range from 0.0 to 0.4 p. p. m. there may actually be water supplies in use that contain more fluorine. On the other hand, all values less than the maximum are omitted, though they may be more representative of general conditions in the county. It is essential to keep this point in mind; for the technical device here used of depicting the maximum fluorine value for a county by shading the entire area of the county may be wrongly interpreted as meaning that that value applies to all places within the county. That this is not so will easily be realized by comparing figure 1, where all known fluorine values for the Dakotas are shown, with figure 2, where only the maximum value for each county is mapped.

For practical use in epidemiological studies this method is defective also; for it does not reveal the nature of individual water supplies and the number of people affected by them. It does, however, show in a general way the sections of the country that suffer from either excesses or deficiencies of fluorine. For studies of conditions in specific areas detailed large-scale maps will be necessary, and in many cases these cannot be made until more water supplies have been tested for fluorine.

THE SOURCE OF THE FLUORINE

In rock analyses, as in water analyses, fluorine has seldom been mentioned until recently because of the lack of accurate methods of determining it in small amounts. Clarke¹¹ estimated that it makes up about 0.027 percent of the earth's crust. However, more recent investigations by Shepherd,¹² based on new methods of analysis, indicate that fluorine is more abundant than this, making up at least 0.04 percent of the earth's crust.

Information on the amount and distribution of fluorine in rocks is still far from complete, but enough is known to indicate that it is present in markedly differing amounts in different kinds of rocks. Shepherd found the highest average concentration (0.07 percent) in obsidian; the lowest average (0.01 percent) was found in more fluid lava flows, from which the fluorine evidently escaped with ease. Of course, fluorine contents much greater than these averages have been

¹¹ Clarke, F. W., *The data of geochemistry*, U. S. Geol. Surv. Bull. 770, 5th ed., 1924.

¹² Shepherd, E. S., *Note on the fluorine content of rocks and ocean-bottom samples*, *Amer. Journ. Sci.*, vol. 238, pp. 117-128, 1940.

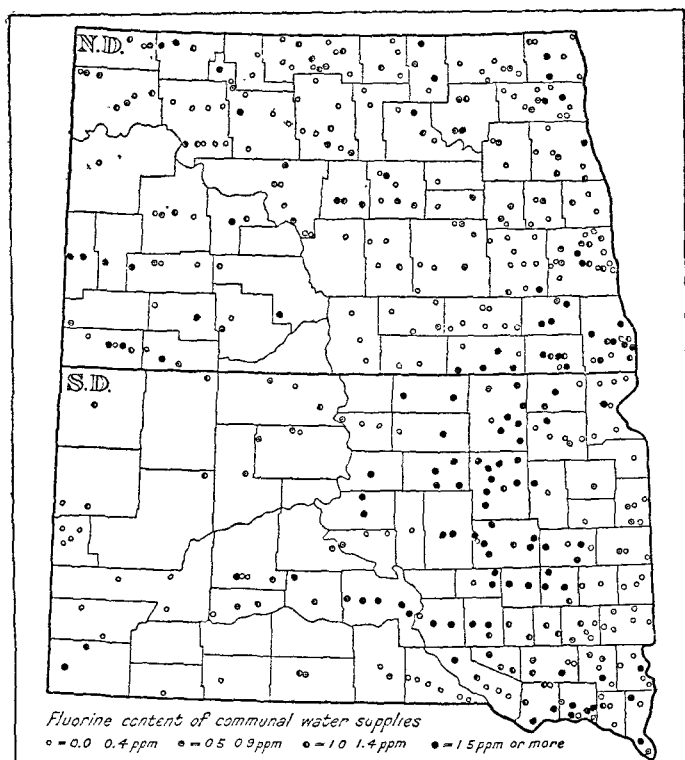


FIGURE 1.—Distribution and classification of known fluorine analyses of communal water supplies in North and South Dakota. See figures 2 and 3 for a clarification of the regional pattern.

FIGURES 2 AND 3 (facing page).—Distribution of the maximum known fluorine content in water supplies of North and South Dakota by counties. Figure 2 includes both communal and noncommunal supplies; figure 3, communal supplies only. Distribution is shown in relation to the geological formations tapped, the key to which is given in table 1. (Note that table 1 refers to North Dakota only.)

TABLE 1—NORTH DAKOTA, FLUORINE IN COMMUNAL WATER SUPPLIES							
<i>From N Dakota Geol. Survey Bull. II</i>							
FORMATION	Symbols Figs. 3, 4	Number of Analyses	Number with Fluorine content of				Average Fluorine content ppm
ALLUVIUM	○	23	14	3	1		0.39
LAKE DEPOSITS	+	25	16	3	6		0.58
GLACIAL DRIFT	◆	145	91	32	15	7	0.50
unconformity							
WHITE RIVER							
unconformity							
FORT UNION	▲	50	18	12	7	13	1.11
LANCE	◆	15	4	4	3	4	1.09
unconformity							
FOX HILLS	■	3	1	1		1	1.33
PIERRE	◊	24	15	4	3	2	0.48
NIOBRARA							
BENTON	△						
DAKOTA	●	33		1	4	28	3.45

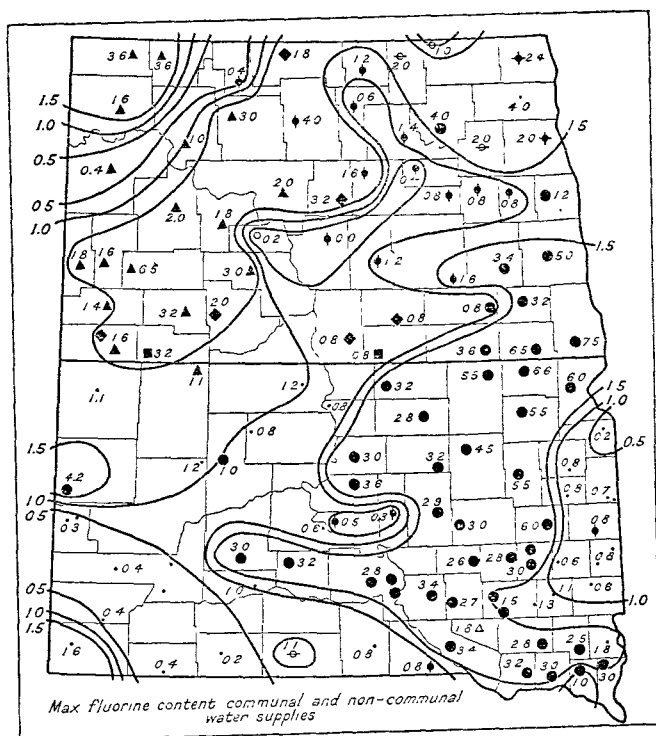


FIGURE 2.

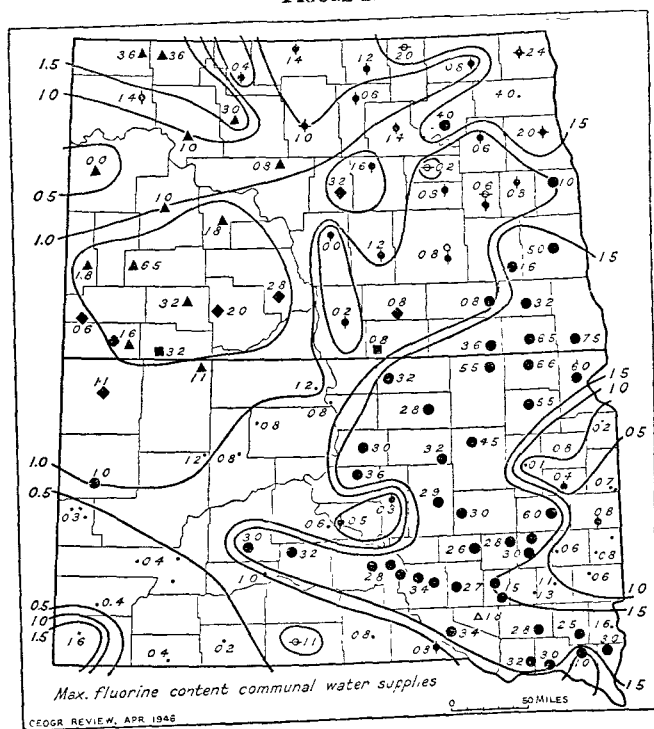


FIGURE 3.

observed in individual rocks. For example, the granites of the Pikes Peak area contain from 0.04 to 1.00 percent of fluorine, present in the form of workable veins and scattered crystals of fluorite and of rare fluorine-bearing minerals.¹³ As a result all the surface streams draining the area contain more than 1.0 p. p. m. of fluorine, enough to make mottled enamel endemic in the Colorado towns deriving their water supplies from these streams. This is one of the few cases of endemic mottled enamel associated with the use of surface waters.

Very few sedimentary rocks have been tested for fluorine. However, since most underground water comes from sediments, it is evident from this study that such rocks differ greatly in fluorine content. In some regions some of the strata contain a considerable amount of fluorine, others very little. Even in one stratum the amount varies from place to place. What is the source of this fluorine in sedimentary rocks? Obviously, some of it is furnished by the weathering and erosion of the fluorine-bearing minerals in igneous rocks, the commoner of which are apatite, tourmaline, topaz, and some of the micas. In some regions fluorine has been added in solutions directly from magmatic sources. This is probably the origin of the fluorspar deposits of Kentucky and Illinois.¹⁴ Yet another source, varying in importance from time to time, is the exhalation into the atmosphere of fluorine gases from volcanoes. Zies¹⁵ has shown that in the Katmai area alone an estimated 135,000 metric tons of fluorine is released yearly, in the form of gaseous hydrofluoric acid. This material, dissolved in rain or snow,¹⁶ is washed out of the atmosphere and contributed to the ground water or the ocean or to sediments forming at the time. Mansfield¹⁷ has suggested that because phosphates and fluorine have an affinity for each other, deposition of such fluorine would tend to be localized in areas where conditions favored the accumulation of phosphates. The resulting fluorapatite is less soluble than the original "bone phosphate" and can be preserved for a long time. Mansfield believes, therefore, that only during times of marked volcanic activity, when large amounts of fluorine are being supplied, can large enduring deposits of

¹³ Clarke, F. W., *Analyses of rocks and minerals . . . , 1880 to 1914*, U. S. Geol. Surv. Bull. 591, pp. 118, 290, and 291, 1915.

¹⁴ Currier, L. W., *Fluorspar deposits of Kentucky*, Kentucky Geol. Surv., ser. 6, vol. 13, 1923; Bastin, E. S., *The fluorspar deposits of Hardin and Pope Counties, Ill.*, Illinois State Geol. Surv. Bull. No. 58, 1931.

¹⁵ Zies, E. G., *The Valley of Ten Thousand Smokes*, Nat. Geogr. Soc. Contr. Techn. Pap., Katmai ser., vol. 1, No. 4, 1929.

¹⁶ It is therefore possible for rain water to contain small amounts of fluorine before it touches the ground. W. H. MacIntire, W. H. Shaw, and B. Robinson (*A barium-fluorine study: The fate of added barium silicofluoride and its effect upon sulfates and other soil components, as influenced by limestone and by dolomite*, Tennessee Agr. Exp. Stat. Bull. No. 155, 1935) found that the rainfall at Knoxville, Tenn., for 1 year, from July 1933 to July 1934, contained 0.145 p. p. m. of fluorine. They suggest that most of it came from the smoke and soot from bituminous coal.

¹⁷ Mansfield, G. R., *The role of fluorine in phosphate deposition*, Amer. Journ. Sci., vol. 238, pp. 863-879, 1940.

phosphates be formed. He finds that the major phosphate deposits of the United States can be related to periods of volcanic activity known from pyroclastic deposits.

These conclusions suggest a possible explanation for the wide differences in the fluorine content of sedimentary rocks of different ages and the variation from place to place in rocks of one age. Fluorine from volcanic sources would be supplied intermittently and would be unevenly distributed in space. Its presence in the rocks would not, however, necessarily ensure its entrance into the ground water. In volcanic-ash deposits the fluorine would be present in minerals such as apatite, tourmaline, and some of the micas. That washed out of the atmosphere as a rain-water solution of hydrofluoric acid would enter into new combinations when it reached the ground, much of it probably forming fluorite. Because minerals such as these are relatively insoluble, fluorine, even though present in considerable amounts, could not enter the ground water until the minerals containing it had been decomposed. Gwynne¹⁸ has suggested that much of this may be accomplished by the attack of sulfuric acid formed by the decomposition of pyrite. In sedimentary rocks pyrite is commonly found in fairly large amounts in association with lignite and coal beds, evidently formed by reaction between iron minerals and hydrogen sulfide produced by the decay of organic material. Fluorine in soluble forms should therefore be expected in large amounts where two conditions prevail: (1) an abundance of fluorine-containing minerals, supplied either directly from magmatic sources, directly from volcanic sources (probably furnishing the greatest quantity), or indirectly by the weathering and erosion of igneous rocks; (2) an abundance of pyrite, usually found in association with concentrations of organic material, to facilitate the decomposition of the fluorine minerals. If this hypothesis is correct, it should be possible to demonstrate that many aquifers yielding fluorine-rich waters were formed during periods and in areas of marked volcanic activity, and that they also contain abundant pyrite.

Such a correlation requires first of all a knowledge of the particular aquifer from which a water supply is derived. From a purely practical viewpoint also, this would be desirable as an aid in determining the sources with the most beneficial fluorine concentrations and those to be avoided because of harmful fluorine concentrations. Too often, however, the exact source of the water is unknown. Many well logs are missing or incomplete. Even when they are available and accurate, the well often passes through several water-bearing layers; and unless it is cased and the exact nature and depth of the

¹⁸ Gwynne, C. S., Geological significance of fluorine in Iowa well-waters, *Pan-American Geologist*, vol. 62, pp. 139-140, 1934.

casing are known, it is impossible to determine the composition of the water from individual aquifers.

In spite of these difficulties, enough information is available in some regions to indicate definitely that certain formations yield water with a high fluorine content, and a number of these formations can be shown to have been deposited during periods of volcanic activity.

INSTANCES OF FLUORINE-RICH AQUIFERS

In the Gulf Coastal Plain, for example, deposits of pyroclastic material indicate that explosive volcanic activity was widespread and recurrent throughout Cretaceous and Tertiary time.¹⁹ Sufficient information is not available to prove that all water-bearing formations deposited during these periods of volcanism have a high fluorine content, but some of them definitely do. For example, basal Upper Cretaceous rocks—the Woodbine sandstone and its equivalents—contain volcanic materials over a wide area in Texas, Oklahoma, Arkansas, and Louisiana. In northeastern Texas the Woodbine, which in places is lignitic, typically yields water containing more than 1.0 p. p. m. of fluorine, the recorded range being 0.7 to 6.0 p. p. m.²⁰ In Alabama and Mississippi the Eutaw formation, a little younger, contains volcanic-ash deposits, phosphatic material, and lignite, and in Alabama it is the chief source of the fluorine in the water supplies.²¹ In Sarasota County, Florida, the Hawthorn formation, Miocene in age, contains volcanic material and phosphates and furnishes water high in fluorine (1.0–3.4 p. p. m.).²² In Louisiana, also, toxic amounts of fluorine occur in water from a Miocene sandstone containing tuffaceous material.²³ For one of the formations in this region yielding water notably high in fluorine, no relationship with volcanic activity has yet been found. This is the Trinity formation, of Lower Cretaceous age, an important aquifer in northeastern Texas. The basal part of it is lignitic and may therefore contain pyrite.

In the central and northern Great Plains also, Cretaceous and Tertiary rocks contain much volcanic material, and lignite and associated

¹⁹ For a summary of the literature on this subject see Ross, C. S., Miser, H. D., and Stephenson, L. W., *Water-laid volcanic rocks of early Upper Cretaceous age in southwestern Arkansas, southeastern Oklahoma, and northeastern Texas*, U. S. Geol. Surv. Prof. Pap. 154-F, 1929.

²⁰ Sundstrom, R. W., Hastings, W. W., and Broadhurst, W. L., *Public water supplies in eastern Texas*, 2 vols., Texas Board of Water Engineers, 1945.

²¹ Carlston, C. W., *Fluoride in the ground water of the Cretaceous area of Alabama*, Geol. Surv. Alabama Bull. 52, 1942.

²² Bay, H. X., *The bleaching clays of Florida*, in *Clay investigations in the southern States, 1934–35*, by W. B. Lang, P. B. King, et al., U. S. Geol. Surv. Bull. 901, pp. 302–317, 1940; Stringfield, V. T., *Ground water resources of Sarasota County, Fla.*, 23d–24th Ann. Rep. Florida State Geol. Surv., 1930–32, Tallahassee, pp. 121–194, 1933; unpublished water analyses of the U. S. Geological Survey.

²³ Maher, J. C., *Fluoride in the ground water of Avoyelles and Rapides Parishes, Louisiana*, Louisiana Geol. Surv. Geol. Pamph. No. 1, 1939.

pyrite are abundant.²⁴ Because for part of this area, North and South Dakota, fairly complete information was available on both the fluorine content of the water supplies and the aquifers from which these supplies are derived, the Dakotas were chosen as a sample area to demonstrate methods and problems of mapping these factors (figs. 2 and 3). Examples in this region of formations containing pyroclastic material and pyrite associated with lignite, and also yielding water with a fairly high fluorine concentration, are the Benton and the Pierre. The Fox Hills sandstone contains volcanic ash and yields water fairly rich in fluorine but is not described as containing lignite or pyrite. On the other hand, the Lance and Fort Union formations, which in western North Dakota are the chief sources of fluorine-rich waters, contain much lignite with a variable sulfur content but are not reported to contain volcanic materials. Over large areas in the Great Plains artesian water from the Dakota sandstone is the chief, and sometimes the only, dependable source of water, but most of the samples analyzed showed toxic amounts of fluorine, enough to cause severe forms of mottled enamel. Even before the cause of mottled enamel had been determined, it was known that in several areas this malady had appeared simultaneously with the installation of artesian wells tapping the Dakota. There are frequent occurrences of lignite in this formation, sometimes with notable concentrations of pyrite, but only a rather remote relation to volcanic activity can be demonstrated.

No mention can be found in the literature of volcanic materials in the Dakota sandstone within the United States. In the eastern Rocky Mountains of Alberta, however, a thin bed of tuff near the middle of the formation has been described, and the upper part contains tuffaceous material grading into the overlying Crowsnest volcanics,²⁵ which were derived from several vents in that area. Since volcanic activity is known to have taken place to the northwest in Alberta and to the south in Arkansas, Oklahoma, and Texas (the Woodbine is correlated with the Dakota), it seems possible that there were other volcanic vents that could have furnished fragmental material to the northern and central Great Plains. Some of the dark shaly layers within the Dakota may prove to be volcanic in origin. On the other

²⁴ Darton, N. H., Preliminary report on the geology and underground water resources of the central Great Plains. U. S. Geol. Surv. Prof. Pap. 32, 1905; Rubey, W. W., Lithologic studies of fine-grained Upper Cretaceous sedimentary rocks of the Black Hills region, *ibid.*, 165-A, 1931; Spivey, R. C., Bentonite in southwestern South Dakota, *South Dakota State Geol. Surv. Rep. Investigations No. 36*, 1940; Stanton, T. W., A Cretaceous volcanic ash bed on the Great Plains in North Dakota, *Journ. Washington Acad. Sci.*, vol. 7, pp. 80-81, 1917; Wherry, E. T., Clay derived from volcanic dust in the Pierre in South Dakota, *ibid.*, pp. 576-583; Wing, M. E., Bentonites of the Belle Fourche district, *South Dakota State Geol. Surv. Rep. Investigations No. 35*, 1940.

²⁵ MacKenzie, J. D., The Crowsnest volcanics, [*Nat.*] Mus. [*Canada*] Bull. No. 4 (Geol. Ser. No. 20), Canada Geological Survey, 1914.

hand, even without the presence of pyroclastic material, fluorine-bearing gases from the known volcanic vents may have furnished some fluorine to the Dakota as it was being deposited. From this source and from fluorine-bearing detrital minerals in the sediments, unusually large amounts of fluorine might be released by the unusually large amounts of pyrite.

In other areas for which the fluorine-yielding aquifers are known, it has not in general been possible to discover any specific conditions that might account for the fluorine concentration. In Illinois the Dresbach, St. Peter, and Niagara formations, and in some places the glacial drift, have been identified as sources of toxic amounts of fluorine. In Oklahoma, waters from the Arbuckle, Clear Fork-Wichita, and Ogallala formations, and from recent alluvium are all rich in fluorine. The Ogallala sandstone, of Tertiary age, presents an interesting case. Throughout the Panhandle area of Texas and Oklahoma it is the chief aquifer, but since erosion has cut it off from rainier areas in the Rocky Mountains region to the west, its water must all be derived from local rainfall. Well water from the Ogallala typically has a toxic fluorine concentration, part of which may be acquired from the Ogallala itself, which contains some layers of volcanic ash. Some of the fluorine, however, must certainly be derived from the overlying materials through which the water has to pass to reach the Ogallala. Dr. Edward Taylor, director of dental health, Texas State Board of Health, reports²⁶ that in Deaf Smith County, Texas, the topsoil contains 250 p. p. m. of fluorine. At a depth of 8 feet this increases to 2,500 p. p. m. A number of volcanoes in New Mexico, active in Pleistocene time and erupting ash that was deposited throughout the Great Plains,²⁷ were probably the source of this fluorine. Perhaps similar conditions, with fluorine being supplied from overlying formations, may exist for some of the other aquifers which are apparently rich in fluorine but for which no explanation of the fluorine content is evident.

CLIMATE AND THE FLUORINE CONTENT OF WATER

Ockerse²⁸ reports that in South Africa the areas of low rainfall "have, generally speaking, a higher fluorine content in their underground water than the high-rainfall areas * * *. The soils and rocks in the low-rainfall areas have not been leached of their minerals to the same extent as those in the high-rainfall areas." Such a relationship can of course be demonstrated only for surface and shallow well waters, since artesian aquifers are not subject to climatic influences. In the United States in general the surface and shallow

²⁶ Letter, December 6, 1945.

²⁷ Landes, K. K., Volcanic ash in Kansas, *Bull. Geol. Soc. Amer.*, vol. 39, pp. 931-940, 1928.

²⁸ Ockerse, T., Endemic fluorosis in South Africa, *Union of South Africa Dep. Publ. Health*, p. 12, 1944.

well waters of the humid East contain little or no fluorine, whereas in some parts of the drier West they contain toxic amounts. In Arizona, for example, most of the high fluorine concentrations are found in shallow wells.²⁹ This is not true, however, in all dry regions. In the Dakotas it is typically the deep artesian waters that have a high fluorine content, and usually the shallow well waters are nontoxic. Since in areas of low rainfall the fluorine concentration varies with variations in geological conditions, it seems unsafe to attribute the contrasts between the humid East and the drier Great Plains to climatic differences. Differences in the nature of the rocks are probably more important.

OTHER PATHOLOGICAL EFFECTS OF FLUORINE

It is known that ingestion of large amounts of fluorine affects the human system in general, producing changes in the bony structure simulating rheumatic conditions. Cases of such chronic fluorine poisoning caused by excessive fluorine in the drinking water have been reported from India, the Argentine Republic and South Africa.³⁰ Experimental studies indicate that other possible effects of fluorine are enlargement of the thyroid gland, producing exophthalmic goiter; reduction of the calcium content of the blood, disturbing body metabolism; rendering of the bones more fragile, causing an unusual number of bone fractures; and development of high blood pressure and nervous disorders.³¹

As far as is known, these types of fluorosis have not been reported in the United States. Since the minimum amounts of fluorine needed to produce them have not been determined, it is uncertain whether they are entirely absent, even where there is enough fluorine to cause dental fluorosis, or have merely not been recognized because of their similarity to disorders caused by other factors. A recent study³² of men and boys from regions with water supplies containing from 0.0 to 5.0 p. p. m. of fluorine shows that bone-fracture experience, height, and weight are not related to this degree of fluorine exposure. Moreover, it was found³³ that a large percentage of the fluorine ingested

²⁹ Smith, H. V., and Evans, Tindall, A fluorine study of wells, *Water Works Engineering*, August 13, 1941 (reprint).

³⁰ For a discussion of the reports and of the general manifestations of bone fluorosis see Ockerse, *op. cit.*

³¹ For a summary of these studies see Abbott, G. A., The fluoride content of North Dakota ground waters as related to the occurrence and distribution of mottled enamel, *North Dakota Geol. Surv. Bull.* 9, 1937; McClure, F. J., and Mitchell, H. H., The effect of fluorine on the calcium metabolism of albino rats and the composition of the bones, *Journ. Biol. Chem.*, vol. 90, pp. 297-320, 1931; McClure, F. J., Fluoride domestic waters and systemic effects. I, Relation to bone-fracture experience, height, and weight of high-school boys and young selectees of the Armed Forces of the United States, *Publ. Health Reps.*, vol. 59, pp. 1543-1558, 1944.

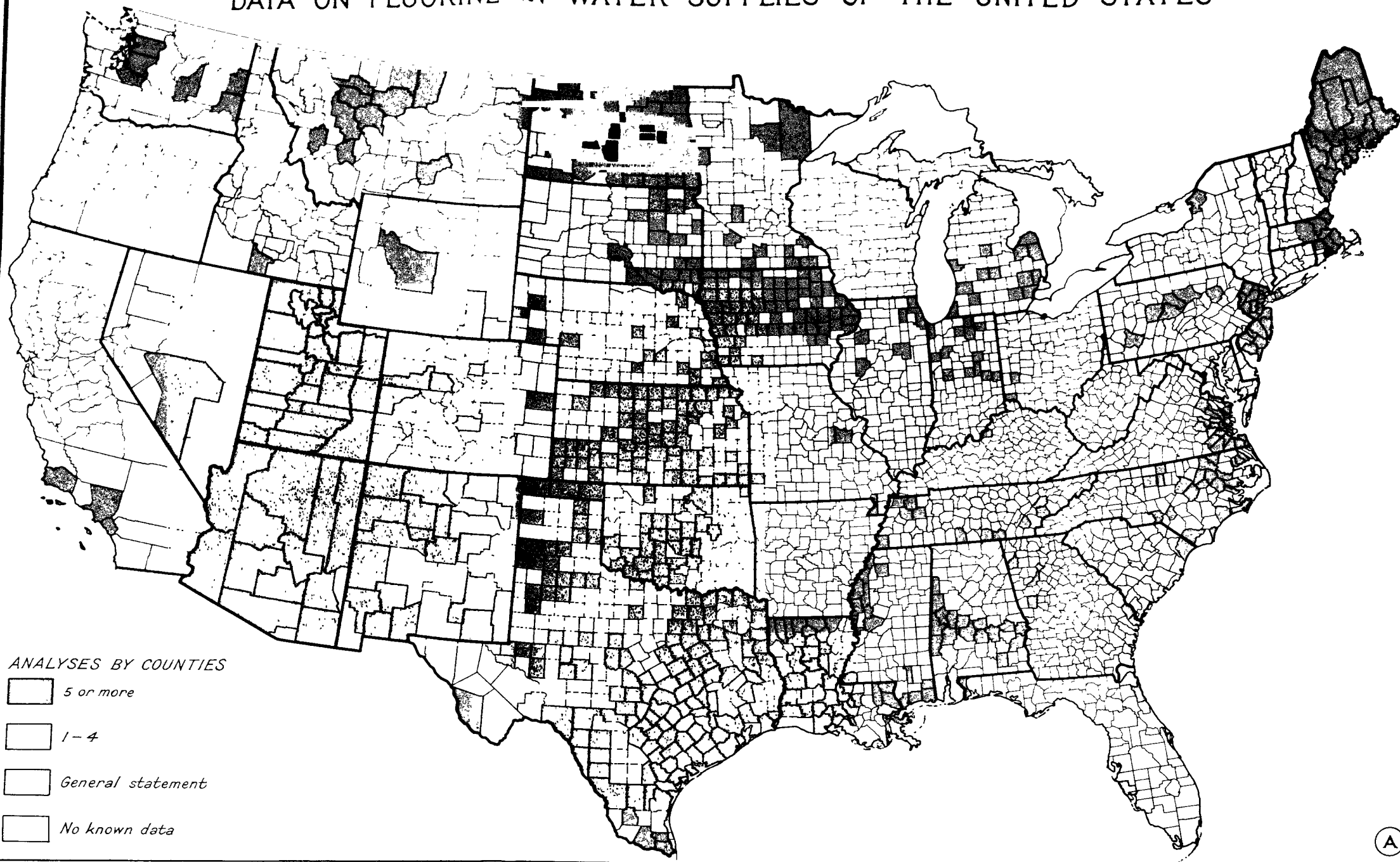
³² McClure, *op. cit.*

³³ McClure, F. J., and Kinser, C. A., Fluoride domestic waters and systemic effects. II, Fluorine content of urine in relation to fluorine in drinking water, *Publ. Health Reps.*, vol. 59, pp. 1575-1591, 1944.

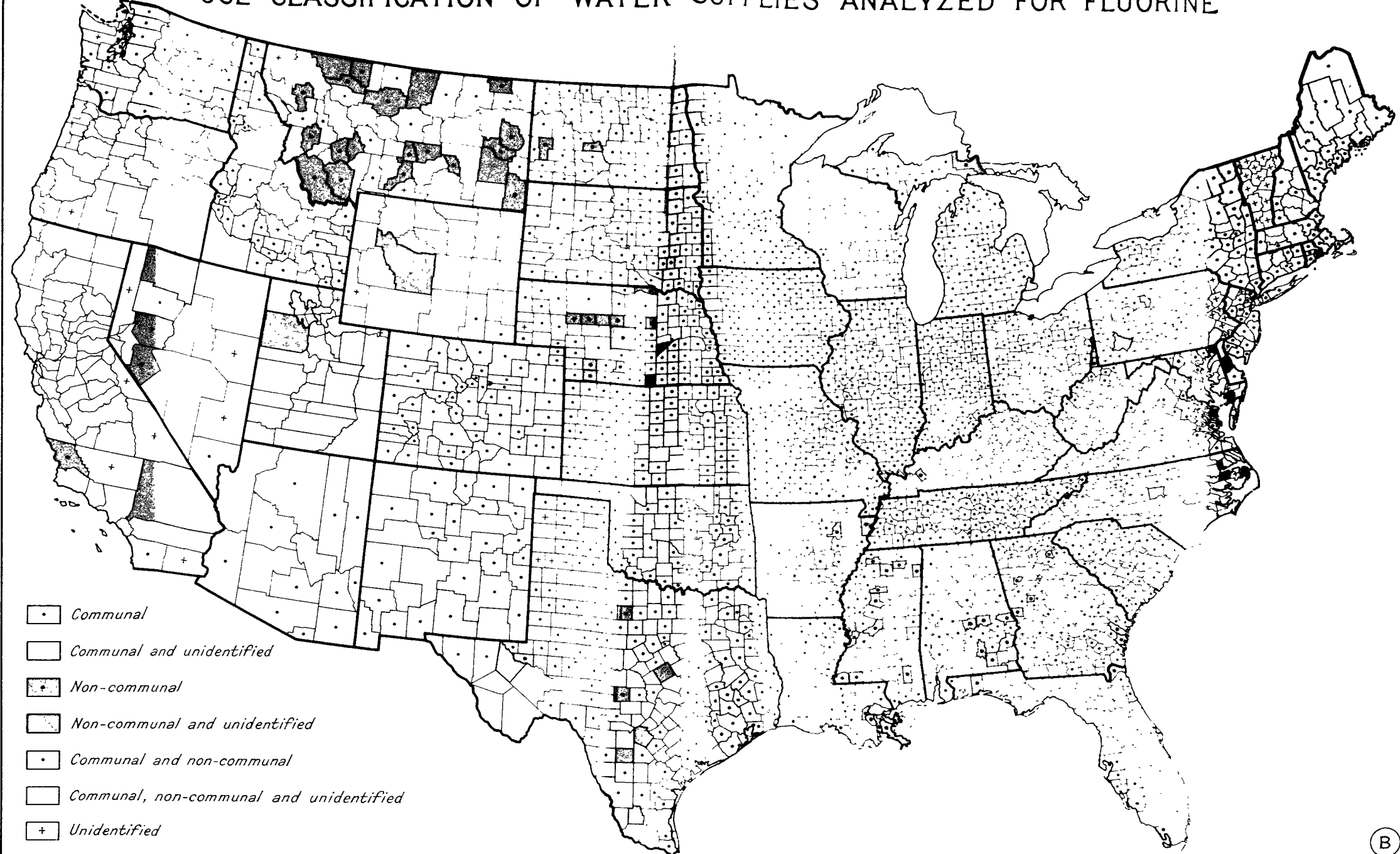
by this group was eliminated in the urine, which greatly reduces the probability of fluorine toxicosis when the fluorine concentration in the drinking water is 5.0 p. p. m. or less. For the effects of higher concentrations, and for other types of fluorosis, more studies are needed.

In conclusion the need for better data on the fluorine content of potable and agricultural waters is urged upon county and State health departments. Tests should be repeated on the same wells throughout the year to determine minimum as well as average and maximum values. Tests should be correlated with depth of well, with populations using the supply (both human and animal), and, wherever possible, with rock analyses at well depths. A copy of this report will be mailed to each cooperating office, and correspondence will be continued until the preliminary map can be redrawn and the study advanced to a more permanent basis.

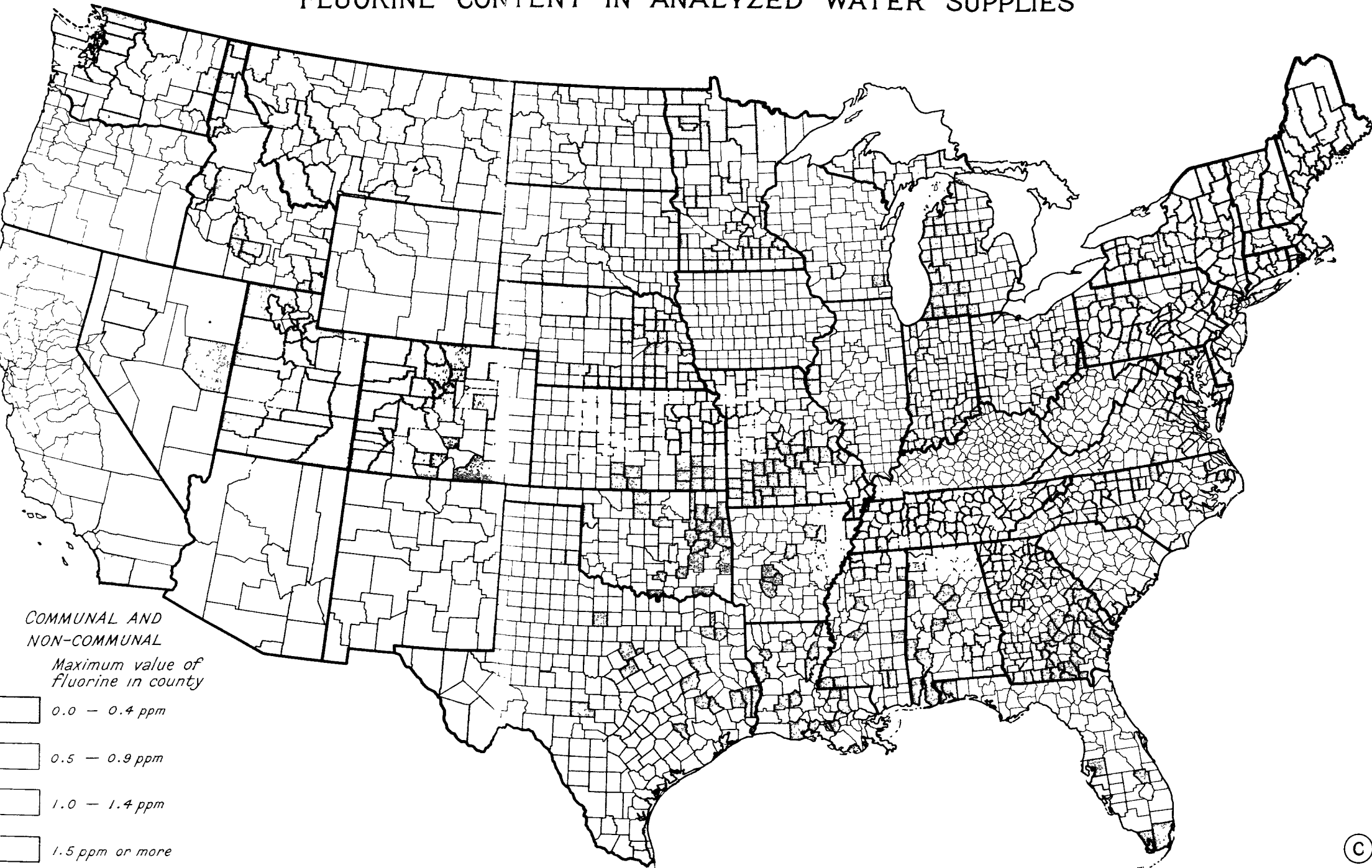
DATA ON FLUORINE IN WATER SUPPLIES OF THE UNITED STATES



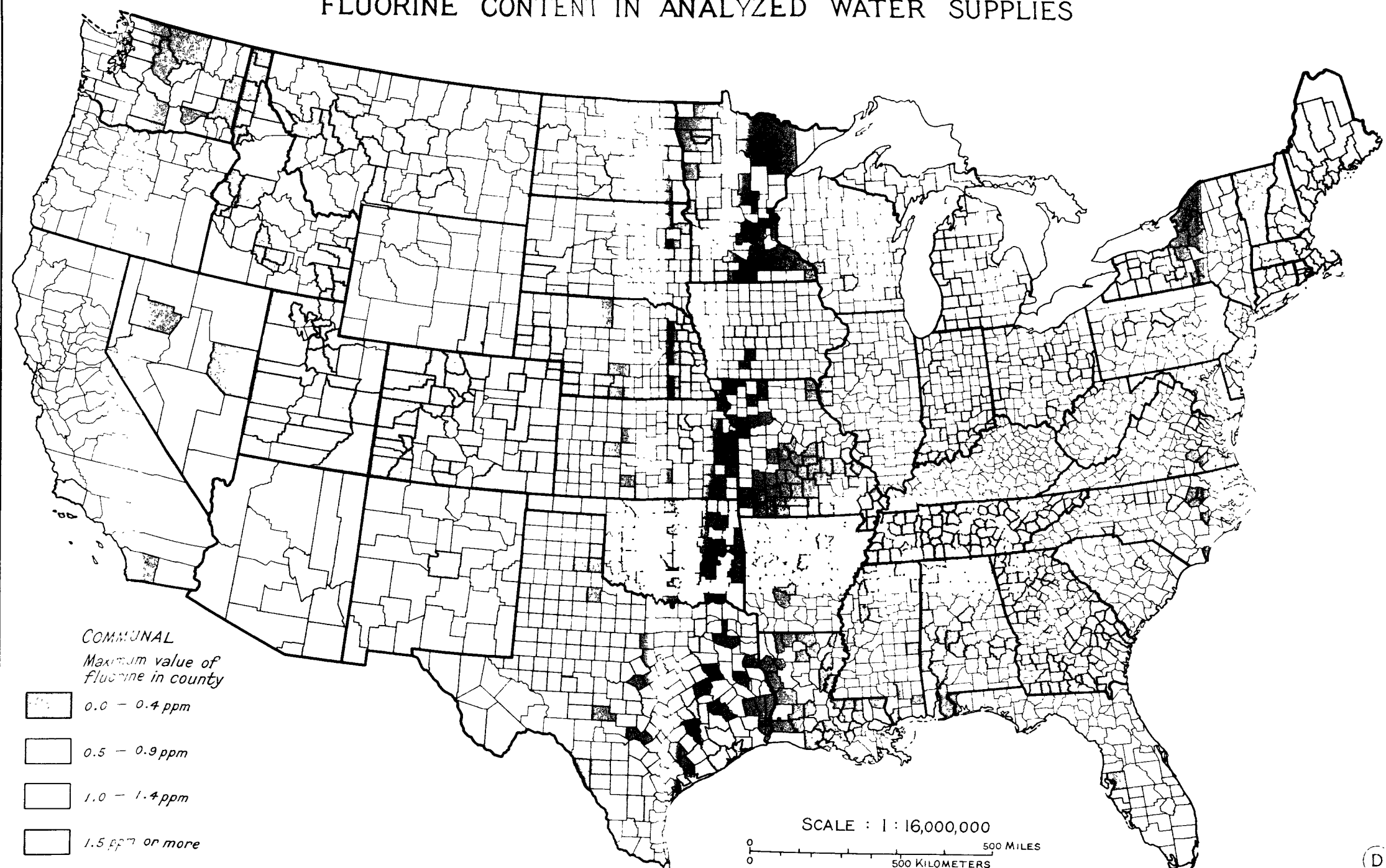
USE CLASSIFICATION OF WATER SUPPLIES ANALYZED FOR FLUORINE



FLUORINE CONTENT IN ANALYZED WATER SUPPLIES



FLUORINE CONTENT IN ANALYZED WATER SUPPLIES



THE BIRTH OF PARÍCUTIN¹

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[With 10 plates]

INTRODUCTION

Many thousands of volcanoes, old and young, are scattered over the earth's surface. Some that are very old have been reduced to traces by erosion, others are still perfectly preserved in their essential form, although cold and inactive. About 500 volcanoes are known to have been active within historical times, although the number of volcanoes in eruption at one time is never large. With very few exceptions the active volcanoes are old and well-established features, antedating the history of man by many years, some having their beginnings a million or more years ago.

In all recorded history there have been but six instances reported of a new volcano being born, that is, originating at a spot with no evidence of previous volcanic outbursts. To these six, we can now add a seventh—Parícutin Volcano—that arose in a cornfield in Mexico on February 20, 1943. The only previously recorded instance in which the outbreak of a new volcano was actually observed is that of Chinyero, Tenerife, which opened up about 100 meters from a farmer and his son.

In the case of Parícutin Volcano, four persons actually saw its beginning at very close hand, and their observations furnish the first adequate account of this rare phenomenon. Others visited the spot after the first outbreak, and scientists were soon on hand to submit it to detailed study. Since there are so many apocryphal accounts of what took place during the first moments of Parícutin Volcano, we will quote, as accurately as possible, the narration of events as

¹ The two authors first saw the new volcano about 1 month after its birth. Thereafter they kept it under observation for a period of nearly 3 years.

recounted to us by the actual eyewitnesses. It is remarkable that, in spite of the tremendous shock and overwhelming fear induced by this sudden apparition, there is so little apparent distortion in their observations.

Michoacan is one of the southwestern States of Mexico, lying due west of Mexico City and touching the Pacific Ocean. It lies in part on the Mexican Plateau, in part in the Tierra Caliente. It is also one of the most beautiful States of Mexico, and owes much of its attraction to its pine-clad volcanic hills, and its lakes formed by dams of ancient lava flows. Although the region contains numerous dead volcanoes, it has had but one active volcano in historic times—Jorullo, which began in 1759 in much the same manner as Parícutin Volcano.

One of the most fertile portions of this region was the municipality of San Juan Parangaricutiro, which included, besides the seat of the Municipio, Parangaricutiro, the villages of Parícutin, Angahuan, Zirosto, Zacán, and others. The area consists of small, rich valleys, devoted to the cultivation of maize, between volcanic ridges and cones covered with forests of pine. As is usual in these regions of Michoacan, the tillable lands are privately owned, but the forest lands belong, in large part, to the villages, and being sources of lumber and turpentine, are an important asset to the community.

The region is inhabited by Tarascan Indians, an indigenous population who have clung persistently to their own language and customs. They are an industrious, deeply religious, yet valiant people, with an innate knowledge of nature such as one finds in a people deeply attached to the soil.

Three kilometers south of Parangaricutiro and two kilometers southeast of Parícutin lay the valley of Rancho Tepacua. Its southern border is the lower slopes of Mount Tancítaro, 3,845 meters high, and the highest point in Michoacan. Its northern border is the ridge called Jarátiro. Between these two mountain areas passed the road from Uruapan to Parícutin. As is the custom in this region the owners of the farms live in the villages, the farms themselves being occupied only temporarily at intervals. The workers travel each day with their oxen and tools from the village to the fields, or to the forest, returning in the evening to their homes.

Between Jarátiro and the foot of Tancítaro, and about 1½ miles from Parícutin Village, lay two rich parcels of land. One, Quitzocho, belonged to the town of Parangaricutiro; the other, Cuiyútziro, to the town of Parícutin. A stone fence separated these two parcels of land and formed the boundary between the two towns. A large rock, called the Piedra del Sol, was also a boundary marker and a landmark. Quitzocho was the property of Barbarino Gutiérrez; Cuiyútziro, that of Dionisio Pulido.

In the minds of many of the simple people of the region, the tragedy that overtook Parangaricutiro and Parícutin is related to events that had their beginnings many years before. When the Tarascans separated to form diverse villages, the town of Parangaricutiro, which became the important center of the area and the town of greatest influence, bought lands from the other villages. Parícutin sold some in Rancho Tepacua, near the parcels of Cuíyútziro and Quitzocho, but the boundaries were never well defined and Parangaricutiro took more land than they had bought (said those of Parícutin). There resulted such a deep feeling of animosity that those of one village hardly dared pass on the lands of the other. This led to numerous altercations on the disputed lands, in one of which Nicolas Toral, of Parícutin, lost his life, almost at the very spot where the new volcano was to break forth.

The ecclesiastical authorities of the Municipio, desirous that the dispute should cease and the two villages live in harmony, placed upon the Cerro del Horno, a huge rock high up on the slopes of Mount Tancítaro, a large wooden cross with plaque of silver, facing Rancho Tepacua. A solemn mass was held at its dedication, attended by a large assemblage of people from many miles around. And so some days passed in peace. But one day it was discovered that the cross had been chopped down and had disappeared. The council of patriarchs, or Teréptich, who gather periodically to deliberate matters of common interest and to augur the signs for the future, considered this event with dark forebodings and prognosticated a punishment without equal, a punishment that would cause their ruin and misery.

BEFORE THE VOLCANO

In the lands of Rancho Tepacua there existed for many years a small hole. Both Dionisio Pulido and his brother Dolores mentioned it as having existed all during their tenure of the land. Each year they cast dirt and debris into this cavity, but it showed no appreciable signs of becoming filled. Sra. Severiana Murilla, now an old lady, recalls how as a child, more than 50 years ago, she played about this small pit. She remembered it well for two reasons: first, because her father warned her to avoid the spot, saying that it was the entrance to an old Spanish mine (although no mining activity has been recorded in the area); and second, because one frequently heard subterranean noises, as if made by falling rocks, near the hole. Further, they amused themselves around the hole because it emitted a pleasant warmth.

Early February is the season of Barbecho, the first plowing of the year, in preparation for the season's sowing. At this time the villagers are in their fields busily engaged in their various tasks. On February 5 the first premonition of the impending disaster was no-

ticed—the earth began to tremble. With each succeeding day the tremors increased, both in number and in violence. Subterranean noises, too, could be heard with increasing frequency and intensity; they seemed to be centered in the area of Cuiyútziro and Quitzocho. These seemingly unnatural manifestations kept the inhabitants in constant turmoil and fear. The earth tremors became so frequent and so violent that it was feared the great church of Parangaricutiro, with its massive walls of masonry more than a meter thick, would collapse. As a precaution, the sacred image of the church, El Señor de los Milagros, famous throughout the region for its miraculous powers, was placed in the main plaza, near the village cross, and by a strange coincidence faced directly toward the spot where the volcano would appear.

FEBRUARY 20, 1943

February 20 was clear and calm. Dionisio Pulido left his village of Parícutin to prepare his farm "Cuiyútziro" for the coming sowing. With him he took his oxen and his plow. He was accompanied by his wife Paula and his son, who would watch the sheep, and Demetrio Toral (who died a short time ago in Calzontzin) to help with the plowing.

In the afternoon, after midday, I joined my wife and son, who were watching the sheep, and inquired if anything new had occurred, since for 2 weeks we had felt strong *temblores* in the region. Paula replied, yes, that she had heard noise and thunder underground. Scarcely had she finished speaking when I, myself, heard a noise, like thunder during a rainstorm, but I could not explain it, for the sky above was clear and the day was so peaceful, as it is in February.

At 4 o'clock I left my wife to set fire to a pile of branches which Demetrio and I and another, whose name I cannot remember, had gathered. I went to burn the branches when I noticed that at a *cueva*,² which was situated on one of the knolls of my farm, a fissure had opened, and I noticed that this fissure, as I followed it with my eye, was long and passed from where I stood, through the hole, and continued in the direction of the Cerro de Canijuata, where Canijuata joins the Mesa of Cocolajara. Here is something new and strange, thought I, and I searched the ground for marks to see whether or not it had opened in the night but could find none; and I saw that it was a kind of fissure that had only a depth of half a meter. I set about to ignite the branches again, when I felt a thunder, the trees trembled, and I turned to speak to Paula; and it was then I saw how, in the hole the ground swelled and raised itself—2 or 2½ meters high—and a kind of smoke or fine dust—gray, like ashes—began to rise up in a portion of the crack that I had not previously seen, near the resumidero. Immediately more smoke began to rise, with a hiss or whistle, loud and continuous, and there was a smell of sulfur. I then became greatly frightened and tried to help unyoke one of the ox teams. I hardly knew what to do, so stunned was I before this, not knowing what to think or what to do and not able to find my wife or my son or my animals. Finally my wits returned and I recalled the sacred Señor de los Milagros, which was in the church in San Juan (Parangari-

² Various referred to by Pulido as a *cueva* (cave or grotto), *resumidero* (a hole or crevice, into which water disappears during the rainy season), or *agujero* (a hole).

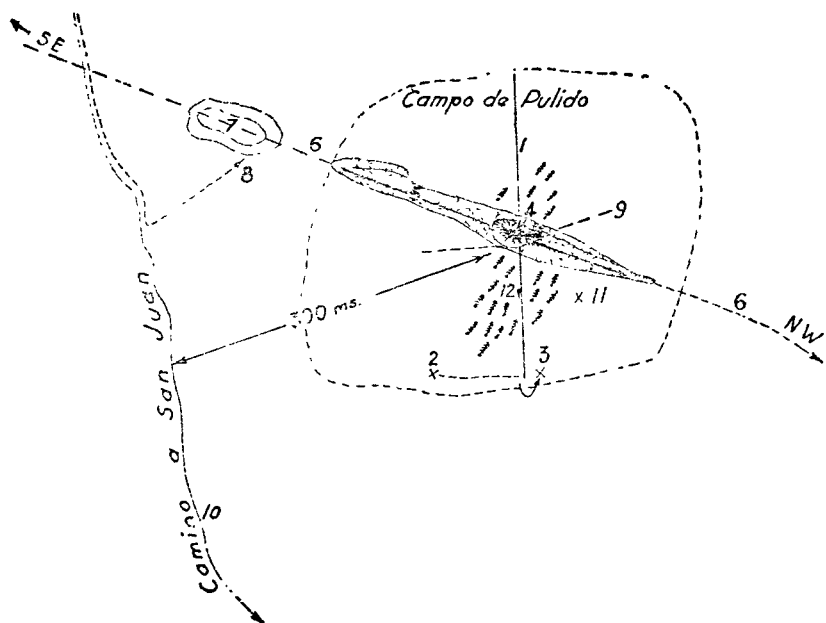


FIGURE 1.—Parícutin Volcano at time of its outbreak, showing position of eye-witnesses.

1. Direction of plow furrow.
2. Dionisio Pulido.
3. Demetrio Toral.
4. Vent of volcano.
5. Depression along fissure.
6. The original fissure.
7. Piedra del Sol.
8. Path taken by Aurora Cuara.
9. A secondary crack of fissure.
10. Road to Parícutin and Parangaricutiro.
11. Paula Rangel de Pulido.
12. Pine trees.

cutiro) and in a loud voice I cried: "Santo Señor de los Milagros, you brought me into this world—now save me from the dangers in which I am about to die," and I looked toward the fissure from whence rose the smoke, and my fear, for the first time, disappeared. I ran to see if I could save my family and my companions and my oxen, but I did not see them, and thought that they had taken the oxen to the spring for water. When I saw that there was no longer any water in the spring, for it was near the fissure, I thought the water was lost because of the fissure. Then, very frightened, I mounted my mare and galloped to Parícutin, where I found my wife and son and friends awaiting, fearing that I might be dead, and that they would never see me again. On the road to Parícutin I thought of my little animals, the yoke oxen, that were going to die in that flame and smoke but upon arriving at my house I was happy to see that they were there.

At no time did Pulido notice any heat in the ground about the spot.

Paula accompanied her husband to watch the sheep. From 8 o'clock in the morning and all during the day she could hear subterranean noises, as if made by a torrent of water dragging stones and logs, or of stones rolling down the mountainside.

About 4 o'clock, after talking to my husband, I heard a kind of loud whistle, like the noise of water falling in live coals or hot embers. This noise was completely distinct from the underground noise I had been hearing and the trees swayed strongly and continuously. I was about 100 meters from the place where these things took place, when I saw, issuing from a crevice that had formed, a little cloud of gray color and I smelled an odor, like sulfur, and I noticed that some pines about 30 meters from the orifice began to burn. I called to my husband. Then the ground rose in the form of a confused cake 2 or 2½ meters high, above the open fissure and then disappeared, but I cannot say whether it blew out or fell back—I believe it swallowed itself. I was sure the earth was on fire and it would consume itself. I am sure that from the fissure arose a gray column of smoke, without force, depositing a fine gray dust.

Very much frightened, Paula fled to Parícutin and there waited with great anxiety to see whether her husband would return. Toral arrived with the oxen.

Aurora de Cuara, wife of Gregorio Cuaro Sota, had been with her family at their farm at San Nicolas, some 20 kilometers from Parangaricutiro. All during the day they felt very strong earth tremors and heard subterranean noises. Aurora and her children were returning afoot to Parangaricutiro along the road that leads directly past Cuiyútziro. At 4:30 p. m., they reached the foot of the Piedra del Sol, precisely at the time when the ground opened up.

As I passed the Piedra del Sol, I felt very heavy earth shocks and saw the earth open up, like a fissure. From this fissure arose a smoke of very fine gray dust to about one-half the height of the nearby pine trees.

Although terribly frightened Aurora clambered to the summit of the rock, in order that she might see what was happening. The fissure was about 50 meters distant. There was no "thunder" but she was able to see that not only smoke and gray dust, but also "sparks" rose from the fissure. She could see Pulido assist his helper unyoke the oxen but could not see Paula because a grove of pines obscured a full view of the farm, and she saw the two men flee in fright toward the village. At the Piedra del Sol, one could hear noises like a roar or like a stone falling down a deep well and striking the sides.

Dolores Pulido, brother of Dionisio, was working in the forest on Cerro de Janánboro. He saw smoke arising from his brother's land and went to see what had taken place. He reached the spot about 6 p. m. and saw, from a distance of 8 meters, smoke issuing from a vent in the ground. About this vent were low mounds of fine gray dust. He was unable to approach closer because of falling stones. He then took fright and fled.

In Parangaricutiro, Luis Ortiz Solorio was standing near his house, talking to his neighbor, the shoemaker. It was a quarter past 5 in the afternoon. Looking toward Quitzocho, he saw a thin column of smoke arising. He went to the plaza, where many people had gathered in front of the church, for news had come that the earth had opened up and smoke was issuing from a crack in the ground. The Cura, Jose Caballero, with the consent of the Presidente, Felipe Cuara Amezcua, decided to send a group of men to the spot to see what had taken place. Solorio offered to go, also Jesús Anguiano, Jesús Martínez, Antonio Escalera, and Miguel Campoverde. Since the Cura believed this mission would be a dangerous one in which they might lose their lives, and to give them spirit, as well as valor, he gave them his benediction.

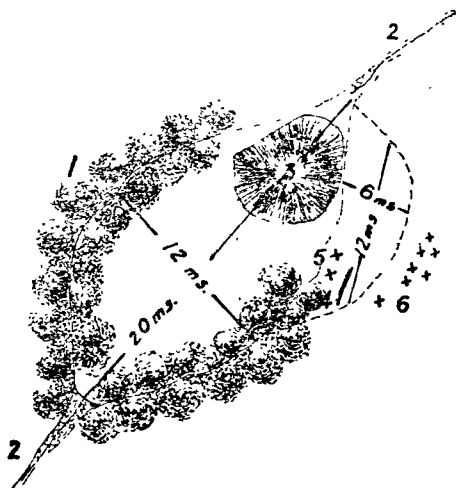


FIGURE 2.—Parícutin Volcano at 6 p. m., February 20, 1943. (From a model made in the soil by Anguiano. Scale in meters.)

1. Small mounds of gray ash.
2. The fissure that opened.
3. The pit from which vapors issued.
4. The fracture that opened while Anguiano and Martínez watched the vent.
5. Anguiano and Martínez.
6. Other members of the Parangaricutiro party.

They went by horse, riding rapidly, and very soon came to the spot, the first two to arrive being Jesús Anguiano and Jesús Martínez. They found that the earth had opened, forming a kind of fissure, at the extreme southern end of which was a hole about half a meter across, from which issued smoke, and red-hot stones were thrown into the air a short distance. Anguiano, desirous to see what was taking place in the hole, approached the spot, when Solorio cried out to come back, the side was about to collapse. Scarcely had he leapt back, when the

wall fell in, widening the orifice to 2 meters across, and the column of smoke increased in size.

According to Anguiano, the orifice was pear-shaped and from this cavity arose a fine gray dust like ashes and "sparks," and stones were thrown out without much force to a height of 5 meters. A choking odor pervaded the spot. In the vent the sand was "boiling" like the bubbling sand in a rising spring, with a noise like a large jug of water, boiling vigorously, or boulders dragged along a stream bed by a river in flood. About the vent small mounds of fine dust half a meter high had gathered. This fine ash was very hot but Anguiano collected some in his handkerchief as well as two of the hot stones.

The ground shook violently, "jumping up and down, not with the swaying motion they had experienced in Parangaricutiro."

They decided then to return and report what they had seen, and they carried with them the ash and the two stones. The stones were delivered to the Cura, and being still hot, they were placed in a dish, and the Cura exorcised them, that the volcano might cease. The Cura and others then consulted a book on Vesuvius in the library of the church, and it was decided that what they had seen was a volcano, which greatly astonished the gathered people.

Between 6 and 9 o'clock the volcano began to throw out large stones, and at 10 o'clock, one could see clearly, from Parangaricutiro, through the pine trees, incandescent rocks hurled out, but without any thunderous noises. Between 11 o'clock and midnight the volcano began to roar, huge incandescent bombs were hurled into the air, and flashes of lightning appeared in the heavy ash column.

On the morning of February 21, Pulido drove his oxen to the forest to graze and then went to his farm to see what had taken place. At 8 o'clock the volcano was about 10 meters high. It emitted smoke and hurled out hot rocks with great violence.

With the outbreak of the volcano, the earth tremors ceased, much to the relief of the populace. The Cura and Presidente allayed their fears somewhat, but on the morning of the 21st a strong earthquake threw them into panic and they abandoned their homes, those from Parícutin fleeing to Parangaricutiro, those from Parangaricutiro to Angahuan or Uruapan, and those from Angahuan to the mountains.

In Parangaricutiro, the village council met under urgent summons from the Presidente. The official account is given in the records of the municipality as follows:

In the village of Parangaricutiro, seat of the municipality of the same name, state of Michoacan de Ocampo, at 10 o'clock on the 21st day of the month of February, 1943, gathered in the public hall of the municipal government, under urgent summons, the Regidores^{*} Felipe Cuara Amezcua, municipal mayor, Felix Anducho, trustee, Rafael Ortiz Enríquez, Ambrosio Soto and Rutilio Sandoval,

^{*} Councilors.

as well as Agustín Sánchez, chief of the Tenancia of Parícutin, of this municipio,⁴ and Dionisio Pulido, resident of said place; the Regidor Felipe Cuara Amezcua, President, declared the session opened, stating that yesterday at about 13 o'clock, Messrs. Sánchez and Pulido presented themselves, telling, greatly excited, of the appearance of a strange conflagration that occurred at 17 o'clock yesterday in the valley called Cuiyútziro, to the east of the village of Parícutin. They asked that they be taken immediately to the place of the happening, that one could see for one's self the truth of their assertion; at the time Dionisio Pulido, owner of the above-mentioned property, gave the information that early on the day of the event, he left his village (Parícutin) to tend his sheep in company with his wife Paula Rangel de Pulido and to visit his properties situated in the said valley; that in the afternoon, at an early hour, he left the place, asking his wife to watch the sheep until he returned; that about 16 o'clock he returned to the place and asked Demetrio Torres⁵ who worked in the fields, to unyoke the oxen and take them to water; after which he returned to his wife suggesting that she return to the village, going then to examine the work done in the fields, arriving at the slope of the nearby hill to the east; that there, about 17 o'clock, he felt a strong tremor and din in the earth, to which he paid little attention, since seisms had been frequent for more than 8 days, but he continued hearing loud subterranean noises accompanying the tremors, and then, thoroughly frightened, he turned his gaze to the west, that is toward his village, observing with surprise that down there in the joyaita,⁶ long tongues of fire arose, with a great deal of smoke and noises never heard before. A terrible panic seized him, and he fled toward Parícutin, where he arrived out of breath, immediately recounting to C. Agustín Sánchez, chief of the Tenancia, what had occurred. That Señor Sánchez, convincing himself of the truth of what Pulido had told him, went with him to the municipal president of Parangaricutiro, where, totally alarmed, they gave the facts to C. Felipe Cuara Amezcua, who with the haste the case merited, went with the informants to the place where the phenomenon had appeared, and later they learned that it was a volcano. Returning to Parangaricutiro, the C. Presidente Municipal summoned the members of the council to attend the present Extraordinary Session and consider this matter, now that the fear has extended to all the nearby villages, soliciting, for this reason, ample powers from the Council to act; he gave as important in the case, that now the volcano grew with real fury and (with it) the panic of the inhabitants of the region who abandoned their homes and possessions. It was conceded at once to C. Felipe Cuara Amezcua, who immediately began action to solve the problem in the best manner, soliciting the help of General of Division don Manuel Avilo Camacho, Constitutional President of the Republic; of General of Division don Lázaro Cárdenas, Secretary of National Defense; of General Félix Ireta Vivieros, Governor of the State; to the Departments of Agriculture and Government, Municipal authorities of Uruapan and to other official agencies, by means of telegraph and telephone. Upon the proposal of some residents of this place and of Parícutin, the correct name that the mentioned volcano should bear was discussed, and after ample deliberation, in which was taken into account the history, traditions, and desires of the people, it was unanimously denominated "Volcano de Parícutin."

Celadonio Gutierrez, a witness to the events from Parangaricutiro, wrote the following account for us:

⁴ A municipio includes the cabecera, or seat of government, and a number of villages, scattered through the area.

⁵ Demetrio Toral.

⁶ Small valley or depression.

The year 1943 began. When I visited a friend on a ranch called Titzicato, some few kilometers south of where the new volcano broke forth, he told me that some tremors had already begun in these places and they heard many noises in the center of the earth. Then these noises and the tremors began to be felt in San Juan (Parangaricutiro) the following month, the 5th of February, at midday, and every day until the 20th. During these 15 days of tremors, there were some stronger than others; when we heard the subterranean noises we awaited the tremor. According to the noise the movement of the earth was strong or weak. They followed each other almost every minute. If they were delayed the noise or the tremor was stronger.

The people could not feel secure or have confidence to remain in their houses to sleep. They knelt down frequently to pray to God that the earth would not sink, such was the movement during so many days of earthquakes. They brought forth the Image of the Santo Cristo Milagroso, of this village, in procession and the earthquakes ceased. I write this because I have seen it and not because it was told to me.

The volcano broke out on Saturday, February 20, at about half past 4 in the afternoon. What a great surprise for my village and for the world! The earth was burned and there began to ascend a small simple column, that grew little by little, a vapor, strange gray in color, rising silently, with an inclination toward the southeast. A little later many people came from Parícutin, which was nearest to the volcano. The Presidente Municipal, don Felipe Cuara A., prepared to move the people from the place, and had already asked, by means of telegraph, for trucks to transport all the people. But the people despaired and began to leave on foot, on horse or on burros, or however they were able.

In the afternoon, when night began to fall, one could hear more noise. These we called "rezaques."¹ Some tongues of flame began to appear, as of fire, that rose about 800 meters into the air, and others even higher that loosened a rain, as of artificial golden fire. At 8 or 9 at night, some flashes of lightning shot from the vent into the column of vapor. The column was now very dense and black, and extended toward the south. It covered the grand mountain of Tancitaro, for the first sands and ashes were in this direction and cast the first cold shadow of the volcano over this area. From this hour the warming rays of the sun, that warmed the mountains and the green fields, so beautiful, ceased, and the green leaves of the trees and smaller plants that nourished the cattle died from the ashes that now began to appear. How strange and rare to see the clouds form, the first clouds of the volcano! Only a short time before the sky was blue, for the dry season had already begun. So, then, we passed the first night, contemplating and admiring this new event.

On the following day, Sunday the 21st, the dense vapors ceased. When the vapors diminished, the noise increased and at 2 in the afternoon they were very strong. With each blast white vapors accompanied by blue fumes arose; the vapors appeared as if one shook a white sheet in the air.

After the first night, it threw up some tongues of fire, which were almost of pure sand. On the following night one noted that they were explosions of bombs and that the stones rose to a height 500 meters. They flew through the air to fall 300-400 meters from the vent. It is a great memory for me to have seen, during these first days, how the first stones fell on the plowed fields of Quitzocho, where I used to watch the cattle of my grandfather.

At 3 o'clock on the morning of Monday, the 22d, there were earthquakes like we never had before. The earth shook for 7 or 8 minutes, with intervals of a few seconds. The people imagined that this was the ultimate agony of a great region. Who could check the great movement of an entire region? Only the

¹ Grumbles (?).

Omnipotent God, in his great power, with his divine omnipotence thought of us; it was He who saved us.*

The first lava that the volcano gave forth, to the east of the little cone, flowed 3 meters per hour, according to the data of Sr. Geologist don Ezequiel Ordóñez, who was sent by the Comisión Impulsora y Coordinadora de México to observe this important novelty. This gentleman, 78 years of age, through his studies and experience, convinced us that there was no danger to our village, and counseled that the people return to their homes. Now this same gentleman showed us the first lava flow, moving like dough, from which fell incandescent rocks from one side or another, such rocks as we knew before, without knowing how they formed. We also saw the malpais, which we knew before, without an idea of its origin. Without doubt, this answers not only how the malpais formed, but also the tillable lands and the mountains that I knew. We saw the lava, as it covered the *Cruza*⁹ made by the yokes of oxen from Parícutin and which needed only 8 days for the sowing. Now one sees an admirable flow of fire, covering the last traces of our footsteps and of the works of man that he made during the life that God permitted him.

During the morning of the 21st the activity of Parícutin Volcano greatly increased in intensity, casting out great quantities of incandescent material to build up its cone. By midday its height was variously estimated at 30 to 50 meters. The amount of ash, however, was relatively small and the eruptive column of less size and vigor than appeared some weeks later.

The first lava began to flow within 2 days after the initial outburst, perhaps sometime during the day of the 21st. It issued as a viscous mass, spreading slowly over the fields of Cuiyútziro and Quitzocho. It moved slowly, about 5 meters per hour, forming a rugged sheet of torn and jumbled lava fragments.

LATER GROWTH

Parícutin Volcano continued to grow with startling rapidity. On February 26 it had reached a height of more than 160 meters, and its explosive activity had increased to an awesome thunderous bombardment, in which immense quantities of viscous lava were hurled continuously into the air; the noise of these tremendous explosions could be heard in many remote corners of Michoacan, and even in Guanajuato, 350 kilometers to the northeast.

In late March the first lava ceased flowing and the eruptive activity changed to a heavy emission of ash, the eruptive column rising to a height of more than 20,000 feet. This ash covered the countryside for miles around, ruining the fields and destroying the forests.

In time the lavas reached both Parangaricutiro and Parícutin, engulfing and destroying them, and scattering their inhabitants to other

* This earthquake had its epicenter in the sea, near Acapulco, and was not directly related to the volcano.

⁹ The second plowing in preparation for the sowing.

areas. Celadonio Gutierrez wrote on February 20, 1946, in his simple diary of the life of the volcano.

Three years ago my village existed tranquilly, without any warning of the volcano as it exists today. Three years ago all parts of this region were beautiful, with fruit trees in the villages and in the fields, green pastures, beautiful lands that demonstrated the wealth of the region, with cattle and sheep, and droves of horses that grazed in the rich fields. Now there remains for me only a memory and a pride to have known it as it was 3 years ago.

Parícutin Volcano has continued to grow up to the present time (1946), although most of the later growth was in width rather than height. The greatest height recorded in 1946 was 1,500 feet.

SUMMARY

After 2 weeks of local earth tremors and subterranean noises, which increased day by day in strength and frequency, on February 20, 1943, about 4 p. m., a small fissure about 25 meters long opened on the farm Cuiyútziro, near Parícutin village. About 4:20 p. m., a sudden explosion opened a small vent about half a meter across at a spot near the west end of this fissure, and a small eruptive column of fine gray ash and small bombs arose from the orifice. This orifice increased in size by the collapse of its walls, reaching 2 meters in diameter at 6 p. m., and the eruption increased in volume. Within the throat of the vent the ash bubbled like the sand in a spring, with a noise like a cauldron of water boiling vigorously. An odor of sulfur pervaded the vicinity of the vent. Small mounds of fine hot ash half a meter high began to collect about the orifice. Between 10 p. m. and midnight heavy eruptions began, with thunderous noises and the ejection of large incandescent bombs.

During the night the cone grew slowly, reaching a height of 10 meters by 8 a. m. During the day of the 21st, activity greatly increased, and the cone grew very rapidly, reaching 30 meters by mid-day. Probably the first lava flow appeared during this day.

Heavy activity, with thunderous noises, continued, with increased quantities of ejected bombs, and the cone rose to a height of over 160 meters on February 26. In late March the first lava flow ceased, and the eruptive activity changed to the heavy emission of ash, the eruptive column rising to more than 20,000 feet. Later flows spread over the area, eventually engulfing the village of Parícutin and Parangari-cutiro.



1 DIONISIO PULIDO, OWNER OF THE FARM
CUYUJIZIRO, WHO SAW PARICUTIN VOLCANO'S
BIRTH



2: DON FELIPE CUARA AMEZCUA, PRESIDENTE MUNICIPAL
OF PARANGARICUTIRO
(Photograph by W. F. Foshag)



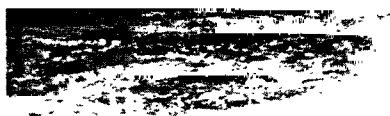
1. FIRST PHOTOGRAPH OF PARÍCUTIN VOLCANO, FROM THE OUTSKIRTS OF PARANGARICUTIRO. FEBRUARY 20, 1943, 5 P. M.

Canjuata Hill on the right.



2. FIRST DAY. FEBRUARY 21, 1943.

The cone is about 30 meters high. (Photograph by Dr. J. Trinidad Hernandez, from Three Lions.)



1. SECOND DAY. FEBRUARY 22, 1943.

The great quantity of ejected bombs and the first lava flow are distinctly visible. (Photograph by Rufus Morrow, from Three Lions.)



2. THIRD DAY. FEBRUARY 23, 1943

The cone is now 160 meters high. (Photograph by Ing. Ramiro Robles Ramos, from Three Lions.)



1 WOMEN OF PARANGARICUTIRO APPROACHING THE CHURCH ON THEIR KNEES TO PRAY THAT THE VOLCANO MIGHT CEASE FEBRUARY 27, 1943
(Photograph by W. F. Foshag)



2 THE CHURCH OF PARANGARICUTIRO, 17 MONTHS LATER, ENGULFED IN LAVA JULY 1944
(Photograph by W. F. Foshag)



1 SECOND MONTH. MARCH 23, 1943

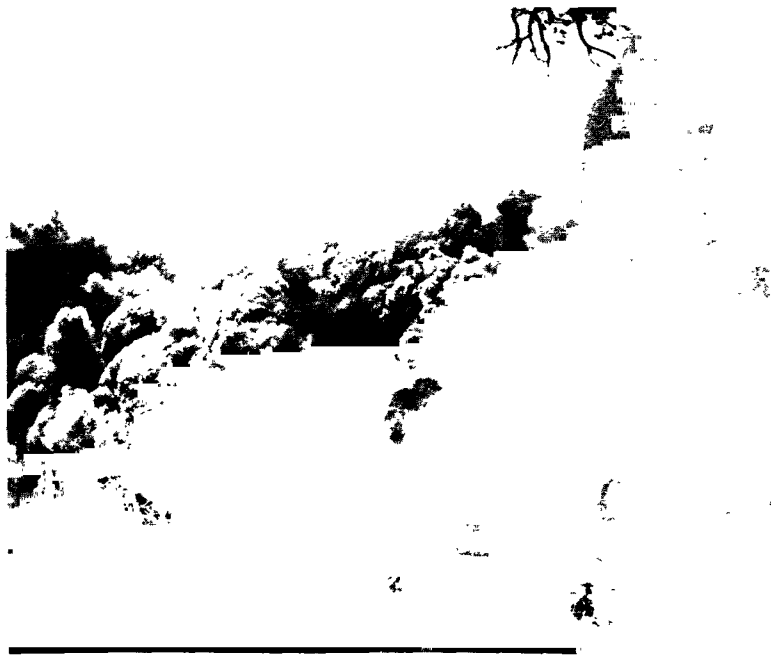
Parícutin Volcano from near Parícutin Village. Front of the first lava flow in middle distance. (Photograph by W. F. Foshag.)



2 THIRD MONTH. APRIL 4, 1943.

Parícutin Volcano from the northeast. Volcanic ash in the foreground, lava flow in the middle ground. (Photograph by Hugo Brehme.)

Smithsonian Report, 1946 Gonzalez and Foshag



1. FOURTH MONTH. MAY 24, 1943.

Parícutin Volcano from the northeast (Photograph by W. F. Foshag)

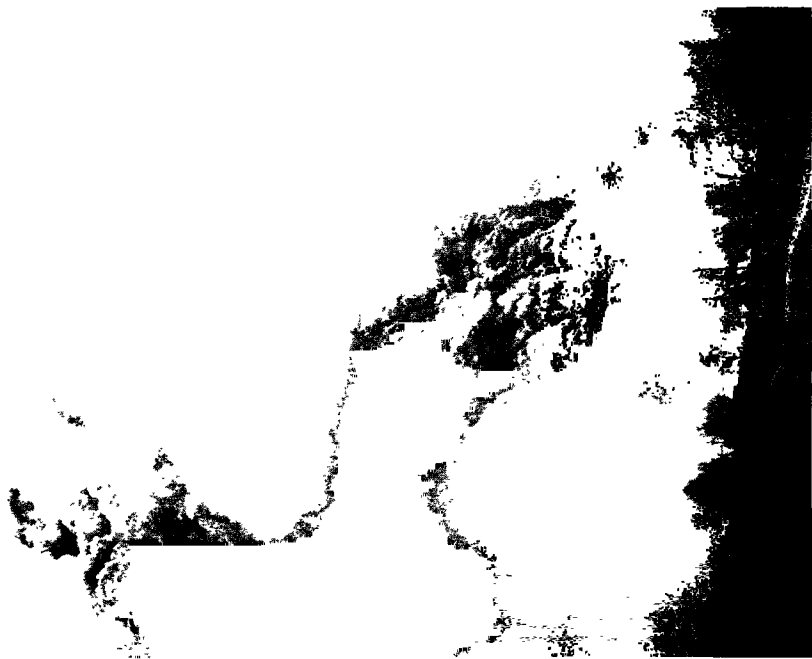


2 FIFTH MONTH. JUNE 9, 1943

From the east The eruptive column reaches a height of over 20,000 feet.
(Photograph by W. F. Foshag)



1 SIXTH MONTH AUGUST 1, 1943.
"Tremendous explosions of viscous lava from the crater" (Photograph by
W. F. Foslag)



2 SIXTH MONTH AUGUST 1, 1943
North side of cone being carried out by a lava flow (Photograph by W. F.
Foslag)



1. BEGINNING OF THE PARANGARICUTIRO LAVA FLOW, AT THE BASE OF THE CONE, JANUARY 8, 1944.

(Photograph by W. F. Foshag.)



2. PARANGARICUTIRO LAVA FLOW APPROACHING THE CHURCH OF PARANGARICUTIRO. JULY 7, 1944.

(Photograph by W. F. Foshag.)



1. FRONT OF THE ZAPICHO LAVA FLOW MARCH 23 1944

(Photograph by W. F. Foshag.)



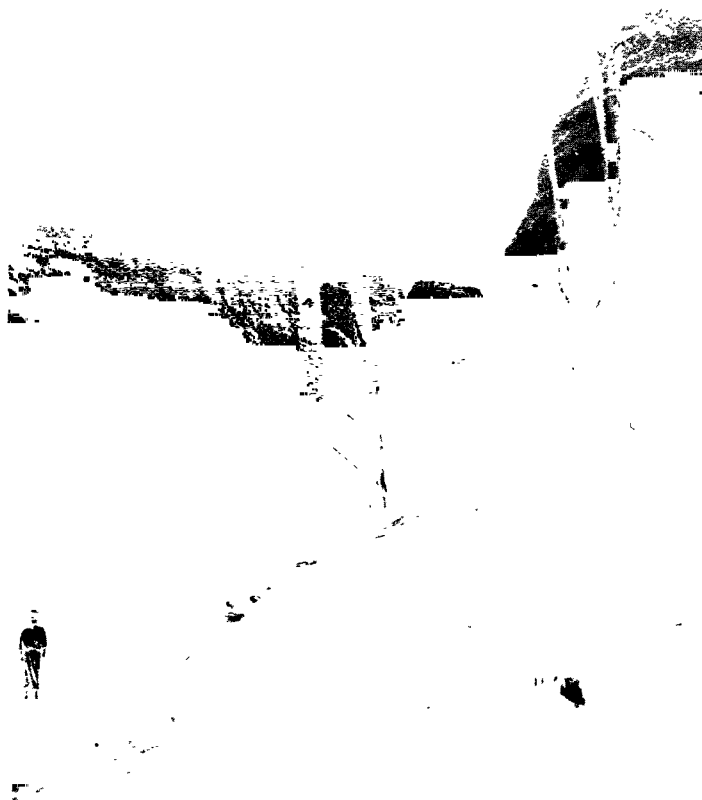
2. INTERIOR OF CRATER JANUARY 23 1945.

(Photograph by W. F. Foshag.)



1 LAVA- AND ASH-COVERED LANDSCAPE NORTH AND WEST OF THE CONE
MARCH 3, 1944.

(Photograph by W. F. Foshag.)



2 RAIN-CUT ARROYO IN ASH NEAR PARÍCUTIN VILLAGE AUGUST 16, 1944.

(Photograph by W. F. Foshag.)

THE NATURAL HISTORY OF WHALEBONE WHALES¹

BY N. A. MACKINTOSH

"Discovery" Investigations, London

[With 2 plates]

I. INTRODUCTION

The whalebone whales (which include all the large species except the sperm whale) generally resort to parts of the open ocean which are remote from human settlements and shipping routes, and they are visible at the surface for perhaps a twentieth of the time they spend submerged. They are thus not easily accessible for biological investigations, and their immense bulk, sometimes exceeding 100 tons, makes dissection almost impossible without the aid of machinery. The best means of access is provided by the whaling industry, and most research on whales has made direct or indirect use of the opportunities it provides. In modern whaling factories the carcasses can be examined in large numbers, for they are hauled out of the water and quickly dismembered; much information is to be had from the statistics of catches; and the numbers caught are sufficient to make the marking of whales a profitable method of research. At the same time more independent observations are also needed, for the hunting of whales is affected by geographical and economic factors, weather conditions, the selection of certain species, etc., and the catches in consequence are not strictly representative of the stock. Thus separate observations from ships not engaged in whaling (and perhaps in the future from the air) constitute an important means of studying the distribution, numbers, and habits of whales.

Modern whaling, with the harpoon gun and the steam catcher, has expanded greatly in the twentieth century. It has provided not only the facilities but also the stimulus for research, for hunting on a large scale calls for regulation based on a knowledge of the distribution and migrations of the species, the reproductive capacity of the stock, and the nature of the populations of whales in different regions. It is with these subjects that the present article is principally concerned;

¹ Reprinted by permission from *Biological Reviews*, vol. 21, No. 2, 1946.

that is to say, with whales from the collective rather than the individual point of view.

The different sources of information and methods of research on these aspects of the biology of whales can be conveniently indicated by the following brief classification of the relevant literature.

From time to time men engaged in the whaling industry have written of the natural history of whales. In the literature based on the old-time industry it is often difficult to sift accurate observations from exaggerated statements and misconceptions, but Scoresby's "An Account of the Arctic Regions" (1820) contains observations of real value, and further useful information from first-hand experience of whaling is given, among others, by Scammon (1874), Risting (1912) and Ingebrigsten (1929). Research has also been carried out by the coordination of data at second hand from various sources, and such work is often of greater scientific value than the statements of whalers which are sometimes difficult to check. An important example is Esricht and Reinhardt's monograph on the Greenland right whale (1861) which is still one of the best sources of information on this species. Kellogg's summary (1929) of all available information on the migrations of whales is of special value, and contains an exhaustive list of references. Some papers by Harmer, Hjort, and others may also be included in this category.

Since the development of modern whaling, individual biologists have sometimes made visits to shore stations and examined a limited number of whales. Observations were made on sizes, external characters, food, breeding, etc., and papers were published in which the results of these observations were generally combined with information obtained locally from the whalers, and with data from other sources and previous publications. Guldberg (1886) appears to have been the first to study the breeding cycle from dated foetal lengths. Cocks, Collett, and Haldane published a number of papers which need not be referred to here in full, True (1904) gave an exhaustive account of the characters of the principal species, and the later work of Allen, Andrews, Barrett-Hamilton, Burfield, Hamilton, Hinton, Hjort and Ruud, Lillie, and Olsen will be referred to below.

Some important recent research is based on the published statistics of the catches of the whaling industry and additional unpublished data contained in the log books of whaling ships. Hjort, Lie and Ruud (1932-38) and Bergersen, Lie, and Ruud (1939, 1941) analyzed the catches in the Antarctic from year to year, with special reference to distribution and the effect of whaling on the stock. Townsend (1935) drew up a series of charts based on the log books of the old American whaleships and showing the positions of capture of thousands of right, humpback, and sperm whales; and on a similar basis

Hansen (1936) charted the captures of the modern pelagic fleet in the Southern Ocean. Risting (1928) studied the lengths of whales and their foetuses in relation to their distribution and breeding, and D'Arcy Thompson (1918, 1919, 1928), Harmer (1928, 1931), Kemp and Bennett (1932), Ottestad (1938), and others have also published papers based on statistics of the industry.

Direct observations on whales on a large scale and partly by new methods have been carried out by the *Discovery* Committee since 1925. These include principally the detailed examination of some thousands of whales at whaling stations and on factory ships, mainly for the investigation of breeding, growth, and age; the marking of whales at sea whereby direct evidence of their migrations and distribution is obtained; and a long-term program of oceanographic research carried out partly for the study of the whales' environment in the Southern Ocean. General accounts of the results of work at whaling stations were given by Mackintosh and Wheeler (1929) and Matthews (1937, 1938b), and some more specialized aspects are dealt with in various papers by Wheeler, Ommanney, and Laurie. A paper describing the principal results of whale marking has been published by Rayner (1940), and a more general report concerned largely with distribution and the stocks of whales by myself (1942).

Of the investigations which are not dependent on the whaling industry, direct observations at sea have been used in some of the *Discovery* Reports, and other expeditions have resulted in papers on habits of whales, among which those of Racovitza (1903), Lillie (1915), and Bruce (1915) may be mentioned. Stranded whales and museum specimens are mainly of systematic and anatomical interest, but records of standings (e. g., Harmer, 1927; Fraser, 1934) throw some light on distribution.

The principal modern methods of investigating the natural history of whales are (a) anatomical examination in whaling factories, (b) independent observations at sea, (c) the marking of whales, and (d) analysis of the statistics of the industry. Whale marking is perhaps the soundest method of investigating some of the problems which arise. The method is to fire a numbered dart which lodges in the blubber of the living whale, and a reward is offered for the return of the mark with appropriate particulars. Such marks have been recovered up to about 2,500 miles from the position of marking and up to 10 years from the time of marking. Some of the evidence obtained through the catches of whales (under (a) and (d) above) must be applied with caution to the populations in general, but it can often be checked by marking and independent observations. Whale marking not only provides information on distribution and migrations. Recoveries of long-term marks can be used as a check on estimates of

the growth rate and ages of whales, and since there are now some 5,000 marked whales at large in the Southern Ocean, it is expected that new evidence in this connection will be obtained in the future.

II. DISTRIBUTION AND MIGRATIONS OF THE SEPARATE SPECIES

The Mystacoceti, or whalebone whales, include the following species:²

BALAENIDAE (right whales):

Balaena mysticetus Linnaeus. Greenland right whale.

Eubalaena glacialis (Bonnaterre), *E. japonica* Lacépède, *E. australis* Desmoulins, etc. Black right whales.

Neobalaena marginata Gray. Pigmy right whale.

BALAENOPTERIDAE (rorquals, etc.):

Megaptera nodosa (Bonnaterre) (= *M. novaeangliae* (Borowski)). Humpback whale.

Balaenoptera (= *Sibbaldus*) *musculus* (Linnaeus). Blue whale.

B. physalus (Linnaeus). Fin whale.

B. borealis Lesson. Sei whale.

B. brydei Olsen. Bryde's whale.

B. acutorostrata Lacépède. Lesser rorqual or minke.

RACHIANECTIDAE:

Rachianectes glaucus Cope. Gray whale.

These whales are primarily inhabitants of the colder regions, and although most of the species visit temperate and even tropical waters, the largest numbers are seen in comparatively high latitudes. All the species, so far as is known, undertake more or less extensive seasonal migrations (though some species travel considerably greater distances than others), and thus an account of their distribution must include an account of their migrations. In winter the majority move into relatively warm waters, and this is the season in which breeding for the most part takes place. In summer the main herds move into colder waters where planktonic crustaceans offer an abundant food supply. In those species, whose feeding habits have been adequately investigated, it is found that very little food is taken in the warm waters in winter, and the migrations are thus linked with an alternation of feeding and breeding which is a specially important aspect of the general biology of whales.

Although a few whalebone whales (usually humpbacks) occasionally migrate as far as the Equator, there can be very little interchange of stock between the two hemispheres, and they may be regarded as separated by the equatorial regions into a northern and a southern population. The blue, fin, sei, lesser rorqual, and humpback whales of the Northern Hemisphere are regarded as the same species as their

² Dr. F. C. Fraser, of the British Museum (Natural History), has kindly advised me on the nomenclature.

counterparts in the south. The black right whales of the north and south are generally referred to as distinct species, but it is doubtful whether there is good reason for this except insofar as their habitats are separated by a wider equatorial belt than that separating the other species. The Greenland right and gray whales are confined to the Northern Hemisphere, and the pigmy right is known only in the Southern Hemisphere. Bryde's whale is said to inhabit both hemispheres.

Modern whaling takes place mostly in the Southern Hemisphere, and for this reason more is known of the southern than of the northern whales. This applies particularly to their distribution. They are principally inhabitants of the open ocean, and hence the catches of pelagic factories are much more representative of the main stocks of whales than those of shore-based stations. In the north we have little to go on except the data from shore stations, though Townsend (1935) gives some information on the pelagic catches of old whaling ships, mainly in the North Pacific and Southern Oceans. The modern whaling fleet, on the other hand, ranges over most of the Southern Ocean, and here also the marking of whales undertaken by the *Discovery* Committee has provided direct evidence on distribution and migrations. In winter, however, there is little to rely on but the catches of temperate and tropical shore stations.

(1) *Balaena mysticetus*

The Greenland right whale, which grows to a length of about 60 feet, is most readily distinguished by the huge head, which is about a third of the total length. In the great enlargement of the mouth, the elongation of the whalebone plates and modifications of the skull, this species shows a higher degree of specialization than any other whalebone whale. It is also peculiar in having a very restricted range of distribution. No direct investigations on this species have been made in recent years, for although it was formerly abundant in the Arctic it had been hunted almost to extinction by the end of the nineteenth century. The principal authorities are Scoresby (1820) and Esricht and Reinhardt (1861), but earlier work has been summarized in more recent publications. Southwell (1898) gives useful information on its distribution and movements in the North Atlantic, and Townsend (1935) throws new light on its distribution in the North Pacific. Harmer (1928) describes the Greenland right whale as "more polar in its occurrence than any other of the great whales." It was found in large numbers around the coasts and bays of Spitzbergen and Jan Mayen, in the Davis Strait, Baffin Bay, and (probably to a less extent) in Hudson Bay. Townsend's chart shows that it was hunted in the North Pacific in summer mainly in the Sea of

Okhotsk, the northern part of the Bering Sea, and in the Arctic Ocean north of the Bering Strait and along the northern coast of Alaska and Canada. According to Harmer it appears never to go far from the edge of the northern ice, nor to undertake extensive migrations into warmer water during its breeding period. Esricht and Reinhardt considered it to be a migratory animal insofar as it shows a very regular seasonal movement to the north or south as the ice advances or retreats, and Townsend points out that it may actually move farther south than the records of catches suggest, for the species was not hunted in winter (at least in the North Pacific). In the North Atlantic it may occasionally have penetrated as far south as Newfoundland, but it does not occur off the north of Norway or any part of the west European seaboard.

It seems possible that this interesting species will slowly increase in numbers again. The International Whaling Statistics (1930, 1931) record that at Spitzbergen a specimen was taken in 1911, and that in the northeast Pacific 2 were taken in 1923 and 25 in 1924. According to Clarke (1944) it is increasing in the Beaufort Sea (Canadian Arctic) and schools are occasionally reported.

(2) *Eubalaena glacialis*, *E. australis*, etc.

Fraser (1937) uses the term "black right whale" to include the North Atlantic right (*E. glacialis* or *biscayensis*), the southern right (*E. australis*, etc.) and the North Pacific right (*E. japonica*, etc.), and it will be convenient to use the same term here.

Like the Greenland right, these whales grow to a length of not more than about 60 feet, but they are distinguished by a smaller head, and the whalebone is shorter though of a similar fine texture. They have been hunted from the earliest times, and although they have not been reduced to quite such a small remnant as the Greenland whale, they are now protected by international agreement and thus have not been available for research in recent years. Records of their distribution, however, have been summarized in some recent publications, and the following notes are drawn principally from J. A. Allen (1908), G. M. Allen (1916), Collett (1909), Harmer (1928), Townsend (1935), and the International Whaling Statistics.

The black right whales are primarily inhabitants of a comparatively restricted zone in temperate or cold temperate waters, but the latitudes and seasons in which they were caught show a movement toward the Poles in summer and toward the Equator in winter. The North Atlantic right was formerly taken in winter off the Basque coast, and in summer it appears in the records of northwest European stations as far north as the north of Norway. On the American side it is

recorded from New England (in winter) and Newfoundland. The North Pacific right was taken in summer mainly between 40° and 60° N. In winter it was occasionally taken farther south, but rarely south of 30° N. The old whaling grounds on which the southern right was hunted occupy a well-defined zone principally between 30° and 50° S., but again it was taken in small quantities in winter as far north as 20° S. (off the South African and west American coasts). On rare occasions this species, before it was protected, has been taken by the modern industry as far south as the South Shetland Islands (beyond 60° S.), but it is doubtful whether it was ever so plentiful in the Antarctic as in temperate regions, even before it was depleted by the old whalers.

Thus the northern and southern black right whales are separated by a wide tropical belt, and do not normally penetrate into the coldest waters. It must be supposed that the North Atlantic, North Pacific, and southern right whales live in three isolated communities, though the possibility that occasional stragglers move from one to the other should not be finally excluded.

(3) *Neobalaena marginata*

There is little to be said here of the pigmy right whale, for although some stranded specimens have been examined and described, practically nothing is known of its distribution. It has the long, fine whalebone of all the right whales, but externally it differs from the others in its size (not much exceeding 20 feet) and in the possession of a dorsal fin. So far as is known this species is confined to the Southern Hemisphere, and is recorded only from Australia, New Zealand, South Africa, and South America (Péringuey, 1921; Oliver, 1922; Hale, 1931).

(4) *Megaptera nodosa*

It will be convenient to consider this species before any of the other Balaenopteridae because its migrations and distribution are better understood than those of any other whale, at least in the Southern Ocean. This is largely because it resorts to coastal waters in winter where direct observations can be made. The humpback does not exceed about 50 feet in length, but its girth is relatively greater than in any of the species of *Balaenoptera*. It is readily distinguished by the stout body and long flippers. This is one of the more abundant species, and it has figured prominently in the catches of the whaling industry.

Several authors (Risting, 1912; Collett, 1912; Lillie, 1915; Ingebrigsten, 1929; Ommanney, 1933; and Dakin, 1934) state that the southern humpbacks migrate up the coasts of South Africa, Australia, and

New Zealand in autumn, and return southward toward the Antarctic in spring, and Harmer (1931) and Matthews (1937) show that the monthly catches off Angola and Durban reach a peak first in July and then again in September or October, whereas at the French Congo there is a single peak about July and August. These facts accord with the statement that the humpbacks mostly pass the subtropical coasts in the earlier part of the season, and that after some of them have penetrated as far north as the Equator, they return past the subtropical coasts toward the end of the season. From the authors mentioned above, and from Kellogg (1929) and the International Statistics, we find that humpbacks are hunted mainly in tropical latitudes on both sides of each of the southern continents in winter, and in the open ocean in the Antarctic in summer. Conclusive evidence that a long-range migration takes place is provided by whale marking, for a number of marks fired into humpbacks off the pack ice in high latitudes have been recovered by whalers off the northwest coast of Australia, and some also off Madagascar (see Rayner, 1940). It is probable that the majority of humpbacks undertake this migration annually, but it does not follow that all of them penetrate far into the Tropics, and indeed some appear to remain in the Antarctic, for some rare examples have been taken in Antarctic waters at a time when whaling was continued on a small scale through the winter at South Georgia (Risting, 1928).

The marking of whalebone whales in the south has shown that after they have migrated northward they usually return to the same part of the Antarctic in the following summer. This applies especially to humpbacks. Hjort, Lie, and Ruud have published data on the regional distribution of the Antarctic catches of the pelagic whaling fleet. An analysis of their figures (1938, 1939), together with the marking records of the *Discovery* Committee, shows (Mackintosh, 1942) that in summer in the Antarctic the humpbacks are segregated into clearly separate groups in positions which seem to correspond with the separate tropical coastal resorts in winter. Recoveries of whale marks demonstrate that an Antarctic group lying southwest of Australia in summer contains the same whales as appear off the west Australian coast in winter, and a connection has been established between a group south of South Africa and the humpbacks caught in winter off Madagascar. It thus seems highly probable that each of the Antarctic summer groups has its own migration route to the coastal waters of a continent lying approximately to the north of it (see fig. 1). It is to be supposed therefore that the southern stocks of humpbacks are divided into several communities which are for the

most part separated at both ends of their migration routes, and between which there cannot be very much interchange.

The information given by Harmer (1928), Townsend (1935), and the International Statistics shows that in the Northern Hemisphere humpbacks have been found from the Cape Verde Islands to Spitzbergen, from the West Indies to Baffin Bay, from Mexico to the Bering Sea, and from the Mariana Islands (15°–20° N.) to Kamchatka. Again they were hunted in tropical waters in winter and in high latitudes in summer, and this and the evidence assembled by Kellogg leave little doubt that their migrations here are similar to those in the Southern Hemisphere. It is noteworthy, however, that in the north the oceans are relatively restricted in high latitudes, so that the East and West Atlantic stocks and the East and West Pacific stocks may mingle when they migrate poleward in summer. It may be, however, that the populations of the North Atlantic and North Pacific form two entirely separate communities.

(5) *Balaenoptera musculus*

The blue whale is the largest of all species, reaching a maximum length of approximately 100 feet, and although not so numerous as the fin whale it is the most valuable to the modern whaling industry. The "blue whale equivalent," which compares the average production of oil from different species, is taken as 1 blue=2 fin=2½ humpback=6 sei. The various species of *Balaenoptera* are very similar in form, and are difficult to distinguish from one another in the water except by the shape of the dorsal fin. Out of the water, however, they are readily distinguished by the pigmentation, the blue whale having a mottled bluish-gray skin with white flecks over part of the ventral surface.

The blue whale is a widely distributed species. The same may be said of the fin whale, and since the distribution of the latter species is very similar to that of the blue, it will be referred to from time to time in this section. Blue and fin whales are more strictly oceanic species than humpbacks, for they are not concentrated in coastal waters at any time of year. In the Southern Hemisphere they occupy in summer a circumpolar zone in Antarctic waters (well shown in Hansen's Atlas, 1936) which, for at least a large part of the season, is continuous in the Atlantic, Indian Ocean, and Australian sectors, and almost certainly continuous also in the Pacific sector. There is some tendency, however, to concentration in certain regions. Hjort, Lie, and Ruud (1932–38) have shown that the yearly distribution of the whaling fleet indicates a tendency for the blue and fin whales to be

grouped into four principal areas. These are indicated in figure 1, and numbered II-V. The tendency is confirmed by the independent marking records and other observations of the *Discovery* Committee's ships. It is in each of these areas that we find one of the concen-

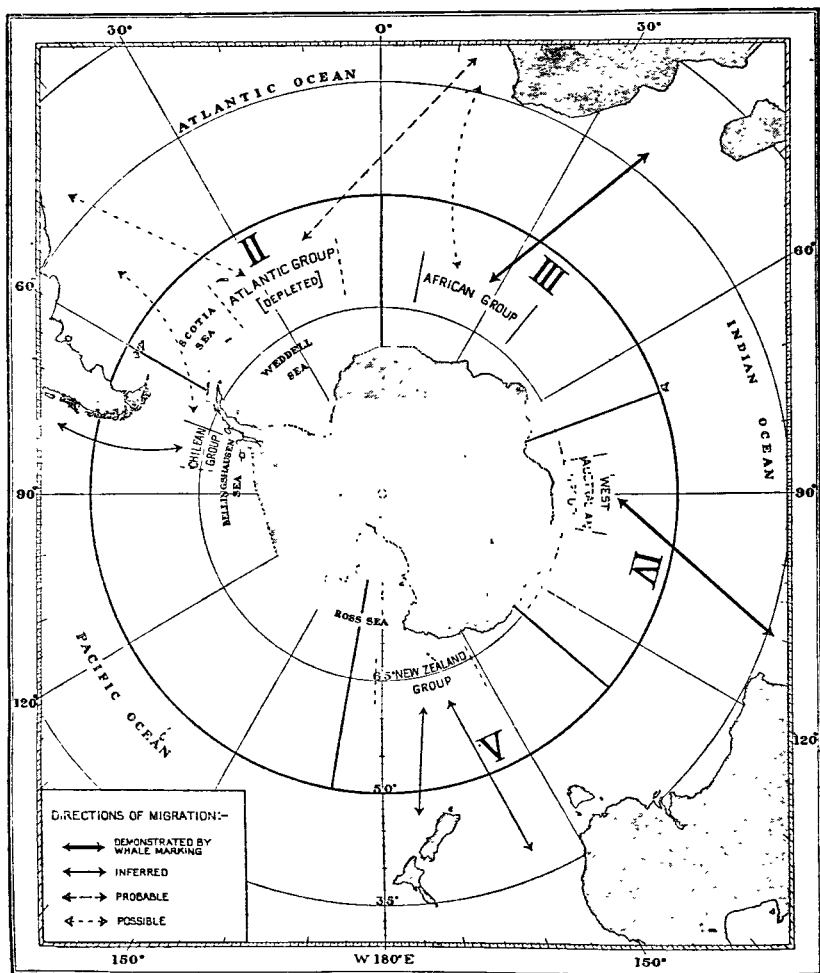


FIGURE 1.—Segregation of the stocks of humpbacks. Large roman numerals indicate Hjort, Lie & Ruud's areas II-V. Short meridional lines show the approximate limits of humpback concentrations in the Antarctic (pecked when uncertain). Arrows indicate the directions of migration. (From Mackintosh, 1942.)

trations of humpbacks (a species which is not taken in sufficient numbers itself to determine the distribution of the factory ships), but whereas the humpbacks are separated into almost completely isolated groups, the blue and fin whales are found in all longitudes, and the grouping is represented only by rather larger numbers. It appears,

however, that the grouping becomes more distinct toward the end of the summer. Rayner (1940) has shown also, through the recovery of whale marks, that there is some interchange of blue and fin whales between one group and another.

In winter a few blue whales (mostly small and immature) are taken off the West African coast as far north as the Congo, in the Indian Ocean up to Madagascar and northwest Australia, and off the west coast of South America as far north as Peru and Ecuador, but it is evident that these shore stations do not tap the main stock, and it is no doubt for that reason that no blue whale marked in the Antarctic has been captured in the warm latitudes in winter. The assumption that they migrate into warmer waters in winter is based on analogy with other species such as the humpback; on the fact that they are not hunted in warm waters in summer or cold waters in winter; on changes in the local composition of the catches (see Harmer (1931), Mackintosh (1942) and others); on variations in fatness which suggest movements to and away from the rich feeding grounds in cold waters (Mackintosh and Wheeler, 1929); and on the incidence of parasites and scars which are believed to be contracted only in cold or in warm waters (Hjort, 1920; Bennett, 1920; Harmer, 1931; Hart, 1935; etc.). The evidence is all circumstantial, but taken as a whole it leaves little doubt that there is at least a general tendency to move toward the Equator in winter, and the Poles in summer.

It is unlikely that the main stocks of blue and fin whales move in a body into tropical waters, for no large numbers of them are recorded as having been seen there. In summer the majority seem to be concentrated in high latitudes in a comparatively restricted zone, but in winter it is possible that they are dispersed over an area more than 10 times as great, and extending from the ice edge perhaps to subtropical regions. If winter concentrations are formed they must presumably keep south of the principal shipping routes.

In the Northern Hemisphere blue whales are recorded from Spitzbergen to the Bay of Biscay, from west Greenland to New England, and from Alaska to south California and Japan and Korea (Harmer, 1928; G. M. Allen, 1916; Hjort and Ruud, 1929; etc.). The evidence for their migrations is similar to that in the south. Kellogg (1929) shows that a seasonal migration is confirmed by the statistics of catches, and the matter is further discussed by most authors who have visited northern stations or analyzed the statistics of catches (see above under Introduction). Little, however, is known of the detailed movements of the northern blue whales. Collett (1912) suggests that in the North Atlantic they spend the winter in the open ocean between the North American coast and the Azores, and move up into Arctic latitudes between Europe and Greenland in summer.

(6) *Balaenoptera physalus*

The fin whale is second in size to the blue, the maximum length being about 85 feet, though specimens over 80 feet are rare. It is by far the most abundant of the large whales, and it is the species on which the modern whaling industry mainly depends. It is distinguished by the coloring which is a plain bluish gray on the back and flanks and white on the ventral surface. The coloring is asymmetrical, the dorsal pigment apparently invariably extending farther down on the left than on the right flank.

The above description of the distribution of blue whales applies in almost every particular to fin whales, but some minor differences are as follows. In the catches of the tropical land stations fin whales are generally even scarcer than blue whales, and it seems likely that they do not normally penetrate so far into tropical waters in winter as the latter species. In summer they tend to keep a little farther than blue whales from the coldest water at the edge of the pack ice. It would appear, therefore, that the range of the fin whale migration is rather less than that of the blue whale, though we cannot be certain of this. In the Antarctic in summer they are found in all longitudes and they show a slight tendency (rather less definite than in blue whales) to concentrate in the areas distinguished by Hjort, Lie and Ruud. The evidence of migration is similar and perhaps a little firmer. There is one record of a fin whale caught off the African coast which had been marked in the Antarctic. Other marking records show that fin whales usually, but not always, return to the same part of the Antarctic after the winter migration. It seems that fin whales mostly arrive in Antarctic waters later in the summer than blue whales, for in the catches of the whaling fleet the proportion of fin whales is small in spring (October–December) but rises sharply about the end of December.

(7) *Balaenoptera borealis*

The sei whale is smaller than the fin, with a maximum length of about 60 feet. The pigmentation is not dissimilar, but the whitish area on the ventral surface is less extensive. The whalebone plates are short as in other rorquals, but resemble those of the right whales in the fine texture of the plates and bristles.

This species inhabits warmer waters than blue and fin whales, and there seems little doubt that it undertakes seasonal migrations (Matthews, 1938b; Kellogg, 1929; Andrews, 1916; and others), but beyond this not very much is known for certain. It is scarce in the Antarctic except at South Georgia where the water is relatively warm. Here it sometimes appears in substantial numbers in late summer. Matthews points out that large catches of sei whales may sometimes

result from a scarcity of other species, but concludes that in fact its occurrence in the catches at South Georgia is representative of its actual occurrence in the sea, and that it arrives at a time when the sea temperature is at its highest. It is commonly taken off temperate and tropical African coasts in winter, where it is probably a little more numerous than blue and fin whales. It also figures in the catches off the west coast of South America and is known in Australasian waters.

In the North Atlantic as in the south it seems to avoid the coldest water, for it does not appear to be recorded from Spitzbergen. It is commonly taken from the north of Norway to Spain, and off Newfoundland and New England. D'Arcy Thompson's charts of Scottish catches (1918, 1919) indicate that whereas blue and fin whales are mostly taken outside the 100-fathom line, sei whales are found both in the shallow water over the continental shelf and in the deep water beyond it. However, Harmer (1927) and Fraser (1934) show that there are comparatively few records of sei whales being stranded on the British coasts. In the North Pacific it is recorded from Alaska to Mexico and Japan.

In some years exceptionally large catches of sei whales have been made in European waters. These may be partly due to scarcity of other whales, but they are probably examples of the irregular movements of this species.

(8) *Balaenoptera brydei*

Bryde's whale is very similar to the sei whale. Olsen (1913) described certain external differences, not all of which were accepted by Andrews (1916). A further publication by Olsen (1926) refers to differences in the baleen, flipper, ventral grooves, etc., and Lönnberg (1931) notes some distinctions in the skeleton. It seems probable that the two species are distinct, but the question should not perhaps be regarded as finally settled yet.

All that can be said of the distribution of this whale is that it is frequently listed in the catches of South African stations and rarely elsewhere. It has been recorded from the West Indies, Lower California, and Norway, but Harmer (1928) considers that its identification, at least at the two latter localities, is open to doubt.

(9) *Balaenoptera acutorostrata*

Except for the pigmy right whale, the lesser rorqual, or minke, is the smallest of the whalebone whales, and seldom exceeds 30 feet in length. Apart from its size it is easily distinguished by a whitish band across the outer surface of the flipper.

This is a widely distributed species but scarcely large enough to

be worth hunting, and little is really known of its distribution. In the North Atlantic it is found as far north as Spitzbergen, and as far south as Spain in the east, and the latitude of New York in the west. A similar whale occurs in the North Pacific (G. M. Allen, 1916). It appears to be a shore-frequenting species, for it is abundant off the coasts of Norway. In the Antarctic Lillie (1915) notes that it is frequently found south of 65° S. Here it is often seen close to land, but it is also seen in open leads in the pack, or near the ice edge, sometimes in large numbers and far from land. It appears that at least in the Southern Ocean it frequents colder water than any other species. There is little information about its seasonal movements, but according to Fraser (1937) its occurrence suggests that such movements do take place.

(10) *Rachianectes glaucus*

The maximum size of the gray whale probably approaches 50 feet. It has a number of features, such as the shape of the head and flippers, which are intermediate between the right whales and the rorquals. It inhabits coastal waters, at least in temperate and tropical latitudes, and living specimens have been recorded only in the North Pacific. Recently, however, skeletons of this species have been found in the Zuyder Zee (Deinse and Junge, 1937).

This is another species which has been severely depleted by hunting, but although few investigations have been possible in recent years, its migrations are, by all accounts, more regular than those of any other species, and the migration route is apparently confined to a narrow coastal strip, at least on the west coast of North America. The principal accounts of its distribution and migrations are those of Scammon (1874), Andrews (1914), and Risting (1928). In summer the gray whales are said to congregate in the Arctic Ocean, Bering Sea, and Sea of Okhotsk, and some at least penetrate into loose pack ice. In winter they migrate southward, appearing off the coasts of Oregon and upper California in October and November, and later assembling for the breeding season in the lagoons of lower California. In spring they move northward again, and according to Kellogg, "by April the gray whales have passed Monterey on their northward run." Similarly, they appear off Korea about the end of November on their way south. According to Andrews they reappear "traveling north, about the middle of March, and by the 15th of May they have all passed by."

Although these descriptions are based on a comparatively small body of data there is no reason to doubt that they are correct, for the limited distribution of this species makes it relatively easy to observe its movements.

III. FOOD

The food of whales is an important subject, since it has a close bearing on their distribution, and is of interest in relation to the general economy of the oceanic fauna. Some of the larger species of planktonic Crustacea, known collectively as "krill," constitute the principal food of the whalebone whales, and it is well known that the baleen (or whalebone) plates, of which the inner edges are frayed out into soft bristles, form an efficient straining mechanism for taking adequate quantities of such organisms.

It is well established that blue, fin, and humpback whales in the Antarctic feed heavily, and virtually exclusively, on the oceanic prawn, *Euphausia superba* (Mackintosh, 1942). This organism is confined to Antarctic waters (John, 1936) and often forms extensive shoals at or near the surface, mainly where the sea temperature is less than 2° C. *E. superba* holds a key position in the chain of nourishment of the Antarctic fauna, for it provides food not only for whales but also for certain fish, seals, and birds. The majority of whales taken in the summer whaling season in the Antarctic are found to have plenty of krill in their stomachs, but those taken in winter at stations in warmer waters in the Southern Hemisphere are found to have eaten little or no food. It is true that these winter catches are not properly representative of the main stock, but there is little doubt that the majority of whales have little to eat in winter, for at the beginning of the Antarctic whaling season the blubber is relatively thin (Mackintosh and Wheeler, 1929), and as the summer advances they become fatter and the yield of oil steadily increases (Hjort, Lie and Ruud, 1938). It is generally assumed that the oil stored in the blubber, bones, and muscles acts as a reserve of nourishment for the winter (Hjort, 1933), and this may be supplemented by small quantities of Crustacea of various species, and occasionally fish. Sei, humpback, and right whales are known to feed sometimes in certain temperate coastal regions of the Southern Hemisphere, on shoals of the "lobster krill" which is the pelagic postlarval (or grimothea) stage of the anomuran, *Munida gregaria* (Matthews, 1932; Rayner, 1935), but this is at the best a minor source of nourishment. The staple summer diet of the southern right and sei whales when they are in sub-Antarctic or temperate waters is not known, but it seems that they also feed on *Euphausia superba* whenever they move so far south as the habitat of this species (Matthews, 1938a, b).

There is much less certainty about the staple food of whales in the Northern Hemisphere. In order to determine the principal food of any species we need not only to identify the organisms found in its stomach from time to time, but also to know whether they are present in large quantities and in a majority of whales, and at what times of

year. The food of the northern whales has been referred to in many publications, but not very many original observations are recorded, and those which give all the required information are scarce. Lillie (1910), Burfield (1912), and Hamilton (1914) examined the stomach contents of blue and fin whales taken in summer off the west of Ireland, and found they were feeding on the euphausiid *Meganyctiphanes norvegica*, "sometimes in immense quantities" (Hamilton), and one or two fin whales, but not blue whales, were feeding on herrings. Perhaps the fullest investigation was that made by Hjort and Ruud (1929) who found that whalebone whales taken off west Norway fed on (i) herrings, (ii) *M. norvegica*, the "large krill," (iii) *Thysanoessa inermis*, the "small krill," and (iv) copepods, mainly *Calanus finmarchicus*. They came to the conclusion that in winter (January to March) the fin whales live on herrings and *Thysanoessa inermis* and in summer exclusively on *Meganyctiphanes norvegica*. G. M. Allen (1916) found large quantities of *Thysanoessa inermis* in the stomachs of blue and fin whales taken off Newfoundland, but the time of year is not stated. Other authors have summarized information from various sources, and it seems that *Meganyctiphanes norvegica* forms at least a substantial part of the diet of blue and fin whales in summer, that at certain times they feed heavily also on *Thysanoessa inermis*, and that the winter diet of fin whales includes fish (herrings, capelin, etc.). Blue whales do not appear to eat fish, and it is not certain whether the majority of fin whales find an amount of food in winter which is comparable to that available in summer.

The humpback, according to Hjort and Ruud, feeds like the fin on "krill" in summer and fish in winter. G. M. Allen (1916) believes that it feeds chiefly on *Thysanoessa inermis* and probably *Meganyctiphanes norvegica* and small fish. Hjort and Ruud show that the food of sei whales off the west coast of Norway consists of *Calanus finmarchicus*. It is interesting that this whale with its finer baleen should eat a smaller planktonic organism, though in the Antarctic it takes the same large euphausiids as other rorquals, and Andrews found that off Japan it ate "*Euphausia*" and sometimes sardines. In the North Pacific Zenkovic (1937) found blue whales feeding on *Nematoscelis*, and fin and humpback feeding partly on fish but also a variety of small Crustacea, some of which were bottom-water forms. Here it would be interesting to know the depth of water in which the whales were hunted.

There is little reliable information on the food of right whales. G. M. Allen (1916) states that the North Atlantic right feeds on *Thysanoessa inermis* and *Calanus finmarchicus*, and the Greenland right is said to feed on *Calanus* and pteropods, but these statements certainly need checking. The stomachs of gray whales caught during their migrations are empty (Andrews, 1914), but in the Arctic in

summer Zenkovic (1937) found that they were feeding on bottom-living amphipods. It is not quite clear, however, whether these really form the staple food of the main stocks of this species.

It is evident that the food of whales in the Northern Hemisphere requires further investigation.

IV. BREEDING, GROWTH, AND AGE

(1) THE REPRODUCTIVE ORGANS

For the purposes of the present article it is not necessary to give a description of the reproductive organs (for this see Mackintosh and Wheeler, 1929; and Ommanney, 1932), but we have to consider certain changes which take place in the course of the sexual cycle, and especially the formation and persistence of the corpora lutea of the ovaries. From this point of view blue and fin whales are the best known, and the following particulars apply equally to both these species except where otherwise stated.

The time of the breeding season has not been determined by direct observation, but evidence is provided by the sizes of foetuses and by the state of the reproductive organs. In the male a seasonal change in the condition of the testis has been observed. The formation of spermatozoa can be seen at all times of the year, but in the early winter there is a greatly increased proliferation of germ cells in the tubules. It is difficult to obtain adequate material from adult whales after the close of the Antarctic summer whaling season, but this period of activity probably lasts from about April to June or July in blue and fin whales in the Southern Hemisphere (Mackintosh and Wheeler, 1929). Although the size of the testis varies considerably in different individuals there is no evidence of an increase in size at the breeding season such as Meek (1918) found in the porpoise. In the female information is obtained principally from examination of the uterus to determine whether a foetus is present or absent, the size and sex of foetuses, the condition of the mammary glands, and the condition of the ovaries, especially of the corpora lutea. In whales the corpus luteum (formed by proliferation of tissue in the Graafian follicle after ovulation) is a conspicuous body which may measure 10 or more centimeters in diameter. At the end of the period of gestation, or presumably much sooner if impregnation has not taken place, it shrinks to a smaller, tougher body which persists certainly for many years and probably throughout the life of the whale (see Wheeler, 1930, and others). These old corpora lutea (strictly corpora albicantia) are thus cumulative. The number to be found in one pair of ovaries varies from 1 to over 50, and, since they give an indication of the number of ovulations which have taken place, they give at least a clue to the age of the whale.

Whales become sexually mature at a length which normally varies within rather narrow limits. The average length for blue whales is about 74 feet in males and 77 feet in females. The corresponding lengths in other species, so far as they have been investigated, are estimated to be as follows: fin, 63 and 65 feet; humpback, about 39 and 41 feet; sei, about 44 and 47½ feet. This is a matter of considerable practical importance, since it allows an estimate to be made of the percentage of immature whales in statistics of catches which give only the species, sex, and length of each whale.

(2) THE SEXUAL CYCLE

Estimates of the time of pairing, the rate of linear growth of the foetus, and the length of the period of gestation, depend primarily on measurements of the lengths of foetuses at different times of year. Records of the largest foetuses and the smallest calves indicate that in blue and fin whales the length at birth is rather more than 20 feet. The average length of foetuses increases rapidly from spring to autumn, and extrapolation of the curve of growth indicates that pairing and calving for the most part take place in winter and that the period of gestation is about a year. The diversity in sizes of foetuses measured at any one time of year shows that pairing and calving must both be spread over a period of several months. This, together with the apparent capacity of the ovaries to produce numerous Graafian follicles (Wheeler, 1930), suggests a prolonged polyoestrous breeding season. These conclusions have been reached by various authors. The work of earlier investigators is summarized by Hinton (1925), and Harmer (1920); and Risting (1928) obtained similar results from an analysis of large numbers of foetal measurements provided by various whaling companies. Risting calculated that in the Southern Hemisphere pairing mostly takes place in blue whales from June to August and in fin whales from June to September. From the increased activity of the testis, the evidence in the ovaries of ovulation about the same time or a little later, and the occurrence of very small foetuses, Mackintosh and Wheeler (1929) inferred that the height of the pairing season in blue and fin whales is about June and July, and estimated that gestation lasts about 10 months in blue whales and perhaps slightly longer in fin whales. Matthews (1937, 1938b) found that in humpbacks the season is probably a little later (August to October) and in sei whales about June to August. Right whales also are believed to pair in winter, and the period of gestation is probably not much different from that of the rorquals. According to Andrews (1914) and Risting (1928) the female gray whales arriving off California and Korea from the north in autumn mostly carry foetuses whose size suggests imminent birth. On the northward migration young have been seen

following their parents and small fetuses have been found. These authors conclude that birth and pairing take place on these southerly grounds in winter, that gestation lasts for about a year, and that impregnation takes place every 2 years. The breeding of this species, like its migrations, is believed to be more regular than in other species, but for confirmation of this it would be desirable to obtain a larger number of measurements of fetuses.

The exact length of the period of gestation and the dates of maximum breeding activity cannot be regarded as precisely established in any species. The important point is that in those species on which adequate observations have been made there is no doubt that breeding mostly takes place in the winter when the whales have moved into warmer waters. In summer the pregnant females move into the high latitudes where food is abundant, and return to warmer latitudes in the following winter to bring forth their calves.

Normally one young is born at a time, and the female is not as a rule reimpregnated in the same year, for parturition is followed by a considerable period of lactation, and instances of whales which are simultaneously pregnant and lactating are rare. In the Antarctic catches of blue and fin whales the proportions of adult females which are pregnant, lactating, and resting alter during the summer months, but these proportions on the whole suggest that a female normally becomes pregnant every 2 years and that the interval may sometimes extend to 3 years (Wheeler, 1930; Laurie, 1937; Mackintosh, 1942).

(3) GROWTH AND AGE

In the rorquals the length at sexual maturity is, very roughly, three times the length at birth, and some estimates have been made of the time taken to grow to sexual maturity. Some direct evidence of rapid growth in fin whales is mentioned by Harmer (1920). Andrews and Risting believed that the gray whale reaches maturity a year after birth. This seems likely enough, since fetuses as long as 17 feet and pregnant females as short as 34 feet are recorded by Risting. The inference that they grow to maturity in a year is based on the occurrence of young whales of intermediate lengths, but it is not clear that the evidence is sufficient to be conclusive. Mackintosh and Wheeler (1929) estimated, from dated measurements of small calves and the relative growth rate of the baleen, that blue and fin whales are generally weaned about 6–7 months after birth, blue whales having by then grown to over 50 feet, and fin whales to 35–40 feet. This, together with some indications of length groups in immature whales, suggested that these whales become adult at an age of about 2 years. The calculation cannot be regarded as fully reliable, and Ruud's evidence (see below) indicates that 3 years is the more usual period. The recovery

of a mark from a whale which Rayner estimated to be about 40–45 feet long at the time of marking, and which measured 68 feet 9 inches when it was killed $2\frac{1}{2}$ years later, suggests growth to maturity in 2 or 3 years. It is to be hoped that further evidence, perhaps from the marking of whales, will be forthcoming in the future.

Up to a point, length is correlated with age, for growth continues after sexual maturity and ends when full physical maturity is reached. This is the point at which all the epiphyses of the vertebrae have become fused to the centra, a process which in whales takes place at a relatively early stage in the caudal region, and is finally completed among the anterior thoracics.

That the accumulations of old corpora lutea are indicative of the age of an adult female is shown first by the fact that whales measuring not much more than the average length at sexual maturity always have comparatively few corpora lutea, while larger whales have various numbers up to 50 or more, and secondly by the fact that there is a close correlation (in blue and fin whales) between the number of corpora lutea and the attainment of physical maturity. Wheeler (1930) found that fin whales with less than 15 corpora lutea were nearly always physically immature, and those with more than 15 nearly always mature. The corresponding number in blue whales according to Laurie (1937) is 11. More recent data, not yet published, suggest, however, that this figure should be a little higher. Since whales appear to be polyoestrous there might be one or more ovulations in each breeding season, with consequent variations in the rate of accumulation of corpora lutea. The correlation, however, between physical maturity and numbers of corpora lutea suggests that there is in fact a fairly steady annual increment. The actual number of years represented (on the average) by a given number of corpora lutea is still, however, in doubt. From the frequencies of numbers of corpora lutea Wheeler inferred that fin whales become physically mature 4–6 years after sexual maturity, which implies about three corpora lutea per annum. Laurie, by a different method, estimated, however, that in blue whales the rate of increment is slightly more than one per annum. A fin whale which was killed 6 years after it had been marked had only eight corpora lutea (Mackintosh, 1942), and in this particular whale the rate cannot have been much more than one per annum. The majority of blue and fin whales taken in the Antarctic are physically immature, and even if only one corpus luteum is added each year, the majority are presumably less than, say, 20 years old. However, it is not yet finally proved that the rate of accumulation cannot be less than one each year, or that none of the oldest corpora lutea disappear in the oldest whales. The largest number found so far is 54 in a fin whale.

Ruud (1940, 1945) describes an important new method of determining the age of a whale from delicate measurements of the thickness of the baleen plates. From gum to tip the thickness decreases in a series of levels, or steps, and there seems little doubt that these represent years of age. The levels are sometimes hard to distinguish, and difficulties arise through the wearing away of the plate at the tip. The method should be of much value for determining the ages of young whales, and gives good reason to believe that sexual maturity is generally reached 3 years after birth in fin whales in the Northern Hemisphere, but further investigations will be needed to test its reliability as a check on the rate of accumulation of corpora lutea in adult whales.

A final point to be mentioned in connection with the growth and age of whales is the relative growth rate of different parts of the body. From measurements of the external proportions of a large number of blue and fin whales Mackintosh and Wheeler (1929) found that in both these species the rate of growth is faster in the anterior than in the posterior part of the body. For example, in female blue whales 13.5 m. in length the head on the average measured 15 percent of the total length, and the tail region 33 percent, but in those measuring 26.5 m. the corresponding figures were 21 and 28.5 percent. Matthews (1937) found a similar effect in the humpback and suggested that the relative increase in the size of the head is connected with the development of the feeding mechanism represented by the whalebone and mouth. In the sei whale, however, he found a more even growth rate which he thought to be correlated with the smaller size of the species and the lower food requirement. According to Esricht and Reinhardt (1861) the head of the Greenland right whale is slightly less than a third of the total length at birth and slightly more than a third in the grown whale. D'Arcy Thompson (1919) found that in fin whales the longer whales had a proportionately larger girth.

V. POPULATIONS AND THE EFFECT OF THE WHALING INDUSTRY

Whales are more or less gregarious animals, and although solitary members of any species are commonly seen they frequently swim in schools of two or more in which they keep within a few yards of one another. Sometimes a number of schools and individuals are found in a limited area, forming what may be loosely termed a herd of whales, but they are often widely dispersed, and it is perhaps best to apply the term "population" only to large groups of whales, such as the fin whales found in Antarctic waters in summer, or one of the principal southern communities of humpbacks.

Although no reliable estimate has yet been made of the actual numbers of whales which make up the population in any region, informa-

tion has been acquired in recent years on the relative numbers of the species and sexes, the constitution of the Antarctic populations, and the nature of the changes brought about by the modern whaling industry. The large whalebone whales are clearly more abundant in the Southern than in the Northern Hemisphere. The oceanic area in which suitable conditions exist for the production of their food is far greater in the south than in the north, and whaling is carried out on an incomparably greater scale. No quantitative comparison has been made, but at least the rorquals of the south must presumably outnumber those of the north several times over. The sex ratio has been examined by Risting (1928), Matthews (1937, 1938b, and Mackintosh (1942), and although the sexes are nearly equal it seems certain that at least in blue, fin, sei, and humpback whales there is a slight majority of males in the Southern, and probably also in the Northern Hemisphere. This is found not only in the statistics of catches, but also in the records of fetuses. Indications are sometimes found of a slight tendency toward temporary segregation of the sexes, or local variation in the sex ratio. For example, there is generally an excess of female humpbacks in the Antarctic catches in summer and of males in the tropical catches in winter. The main herds of fin whales which appear off South Georgia about midsummer seem at first to include a very high proportion of males, but the winter migration of gray whales into warmer latitudes is led by a majority of females.

The catches of the whaling industry give no reliable indication of the relative numbers of the different species, for there is too much selection in this respect, but observations made by the *Discovery* Committee's ships, though limited, are more reliable. A good measure of agreement was found in the ratio of species seen and identified with certainty during voyages of the *Discovery II* and the ratio of species marked or shot at by the *William Scoresby*. This suggested that in the Southern Ocean as a whole in summer the existing ratio of blue, fin, and humpback whales is of the order of 15, 75, and 10 respectively (Mackintosh, 1942). Hjort, Lie, and Ruud (1935, etc.) have shown that the ratio varies in different parts of the Antarctic, largely as a result of whaling, and although allowance is made for this the above estimate must be regarded as provisional. Of the other species right whales are rare and the sei and lesser rorqual are presumably scarcer than the humpback. The lesser rorqual, however, is an inconspicuous whale and may be commoner than observations at sea would suggest. Little can be said of the Northern Hemisphere except that the fin whale predominates in the catches of the modern industry. There is no criterion, however, for comparing the relative numbers of rorquals and right whales before the latter were reduced by the old whaling industry.

Certain changes are worth noting which take place in the composition of the Antarctic population in the course of the Antarctic summer. As the season advances the proportion of blue whales falls while that of fin whales rises. There is a marked decline in the percentage of pregnant females, which become progressively displaced or diluted by the arrival of resting and lactating females; and there is a slightly higher proportion of old and mature whales in the early than in the late summer catches.

It is to be hoped that means will in time be found of making a rough census of the populations of whales, but the problem presents great difficulties. Hjort, Jahn, and Ottestad (1933) considered the possibility of estimating the stock by statistical methods which depend on the relations between the size of the stock and progressive changes in the number caught in a given area, but realized that such methods must involve assumptions which are at present hardly justified. Whale marking might provide information, for the ratio of marked whales killed to marked whales at large should be related to the ratio of total whales killed to total whales at large, but this method also involves incalculable factors. The most direct method would be to count the whales seen in a given area, e. g., the strip of ocean viewed from a ship during a series of voyages; but whales are seen only in fleeting glimpses, and the number observed is so much affected by even slight variations in atmospheric conditions that a reliable count seems impracticable. These are problems for the future, and it may be that a combination of these methods may eventually lead to a rough census when the relevant factors are better understood.

The effect of the whaling industry on the stocks of whales is a large subject, and perhaps not quite within the scope of the present article, but it has influenced the trend of recent research, and something should be said of the location of the industry and of the depletion of certain species. Whaling in the Northern Hemisphere has been confined almost entirely to land stations, and these (of which few have been operating in recent years) are placed at points on the coast accessible to deep oceanic regions, e. g., the west coast of Ireland, the Hebrides, the Californian coast, etc. Many of these localities have been referred to above in the section on distribution. In the Southern Hemisphere whaling was at first conducted from shore bases, mainly at South Georgia, the South Shetland Islands, and parts of the African coasts, but after about 1926 the Antarctic pelagic factories dominated all other whaling. In the years before the war they covered a belt outside the pack ice extending around two-thirds of the Southern Ocean from the South Shetland Islands in 60° W., eastward as far as the Ross Sea (see fig. 1), but did not penetrate to the Pacific sector (60°–180° W.). The International Statistics show that up

to 1908 more than 50 percent of the comparatively small number of whales then killed were from the Northern Hemisphere, but that in 1938 over 90 percent were from the south. The actual figures for that year were: Total, 54,835; Antarctic, 84 percent; Africa, 5.6 percent; North Atlantic and Arctic, 1.4 percent; Japan and North Pacific, 4.5 percent; other regions, 4.5 percent.

The number of whales killed before the war was dangerously high, and there were signs of substantial depletion of the stocks of blue and humpback whales. The evidence for this in blue whales is to be found in the decline in the total catch per catcher's day's work, in the declining percentage of blue whales in the catches, in the reduction in their average sizes and ages, and in the increasing proportion of immature whales in the catches (see Hjort, Lie, and Ruud, 1932-1938; Bergersen, Lie, and Ruud, 1939, 1941; and Mackintosh, 1942). The stocks of humpbacks have probably suffered even more than those of blue whales. Since they are segregated into separate communities depletion is more localized, but the statistics show that it has been very severe in the Atlantic sector of the Southern Ocean. The fact that a higher percentage of marks is recovered from blue and humpback than from fin whales (Rayner, 1940) is further evidence that these are the two species most in need of protection. Fin whales still appeared to be plentiful before the war, but could not be expected to support the industry for long on its prewar scale.

The regulation of the industry is based on the International Agreement of 1937 and Protocols of 1938 and 1944. The principal provisions, which are founded on biological information, are limitation of the Antarctic whaling season, minimum sizes for certain species, geographical limits to the whaling "grounds," the temporary protection of humpbacks, and a temporary limit of the total catch to 16,000 blue-whale units. The last is the most important, but it is a new proposal and is subject to reconsideration.

VI. FUTURE INVESTIGATIONS

Although considerable progress has been made in recent years there is a large field for future research on the whalebone whales. The whaling industry must still offer the most direct means of access to whales, and more work on the same lines as before will be needed, but new or modified methods of research can be developed, and use could be made of some modern technical devices.

Further investigations by biologists working in factory ships are undoubtedly necessary, and have in fact already begun. For practical purposes the condition of the stock must be checked from year to year, and this is specially important at the present time when whaling is being resumed after an interval of some years. More precise in-

formation on breeding and growth is required, and the indications of age from the baleen plates require further attention. The present article is not concerned with anatomy and physiology, but a factory ship would offer scope for further progress in these fields. The breeding cycle of humpbacks could be studied to much advantage if a sufficient number of this species could be examined in winter at a tropical land station.

Whale marking also needs to be continued. It provides data on distribution and migrations, on growth and age, and on the proportions in which different species are removed from the stock by hunting. Marking should if possible be extended to regions other than the Antarctic, such as the warmer southern latitudes in winter, if sufficient numbers of whales can be located. The statistics of catches also will continue to provide material which is instructive in itself and valuable for correlation with other data. New technical devices will no doubt provide new methods of research. "Asdic" should be helpful in studying the habits of whales especially in regard to their underwater movements, and radar might be of much value in counting the number of whales in a measurable area. There are clearly great possibilities in the use of aircraft. The vast extent and severe weather conditions of the principal resorts of whalebone whales would involve difficulties, but aerial observations over sample areas in comparable conditions might go far to assist in the much needed census of the populations. Aerial photographs also can be very informative.

VII. SUMMARY

(1) The whaling industry has provided both the facilities and the stimulus for modern research on the general biology of whales. The principal methods of investigation are (*a*) anatomical examination, (*b*) observations at sea, (*c*) the marking of whales, (*d*) analysis of the statistics of the whaling industry. (2) The whalebone whales are migratory animals, inhabiting high latitudes in summer where food is plentiful, and moving into warmer waters in winter where there is little or no food, but where breeding takes place. The Greenland right whale does not move far from the Arctic regions and is not found in the Southern Hemisphere. The black right whales of the north and south do not migrate far and are separated by a wide tropical belt. The humpback migrates from the polar ice to the Equator, and frequents tropical coastal waters in the winter months. In the Southern Hemisphere it is segregated into several communities which have separate migration routes, and between which there can be little interchange. Blue and fin whales undertake less regular and extensive migrations. They are not segregated like the humpbacks, but show a slight tendency to concentrate in the same regions. Gray whales

inhabit the North Pacific and undertake regular migrations along the coasts of North America and in Japanese waters. There is less information on the distribution of the sei, lesser rorqual, pigmy right, and Bryde's whale. (3) Certain planktonic Crustacea form the principal food of the whalebone whales. In the Antarctic they feed virtually exclusively on the shoals of *Euphausia superba*. In the northern seas the diet seems to be more varied. *Meganyctiphanes norvegica* is probably the most important food organism in the North Atlantic, but further investigations are needed. Little food is taken in winter, though fish and small quantities of other Crustacea are sometimes eaten. (4) Examination of the reproductive organs and measurements of fetuses at different times of year show that breeding mainly takes place in winter and that the period of gestation is about a year. Normally one young is born at a time, and the usual interval between successive pregnancies is probably 2 years. This applies to blue and fin whales, but other species are probably similar. Blue and fin whales are believed to become sexually mature in about 2 or 3 years. The old corpora lutea of the ovaries persist and accumulate, and constitute the best indication so far found of the age of an adult whale. There is some evidence that the rate of increment is about 1 per year, but this again needs confirmation. The largest recorded number is 54. Indications of periodic growth in the baleen plates constitute a new method of determining the ages of young whales. The rate of growth is faster in the anterior than in the posterior part of the body. (5) Whalebone whales are more plentiful in the Southern than in the Northern Hemisphere. The sexes are nearly equal. The existing ratio of blue, fin, and humpback whales is estimated to be of the order of 15, 75, and 10 respectively in the Southern Ocean, but no estimate has yet been made of the absolute numbers in the populations. Most whaling is carried out by the Antarctic pelagic factories, and little is done now in the Northern Hemisphere. The stocks of blue and humpback whales have been depleted by the modern industry, but fin whales have been less affected, and progress has been made in the international regulation of whaling. (6) In the future it will be necessary to continue research to some extent on the same lines as before, but new or modified methods could be developed, and aircraft and modern technical devices might be used with advantage.

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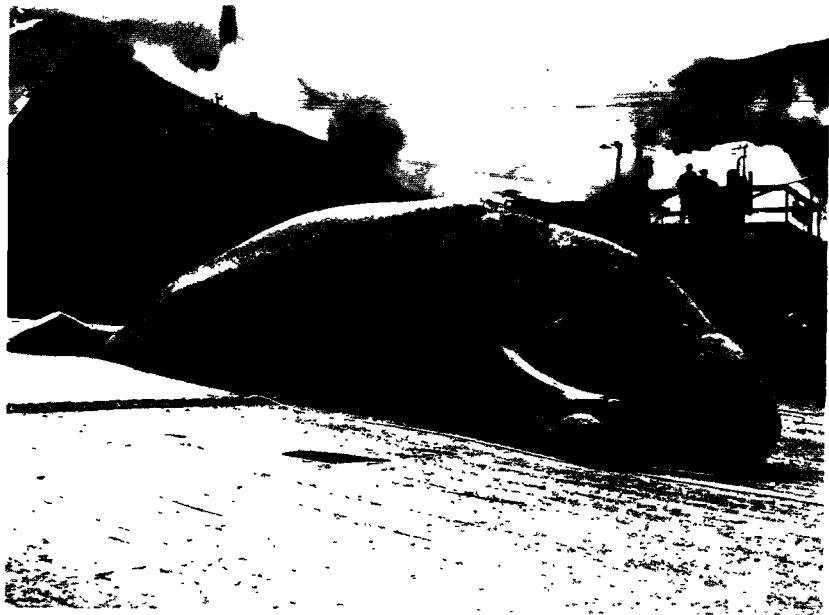
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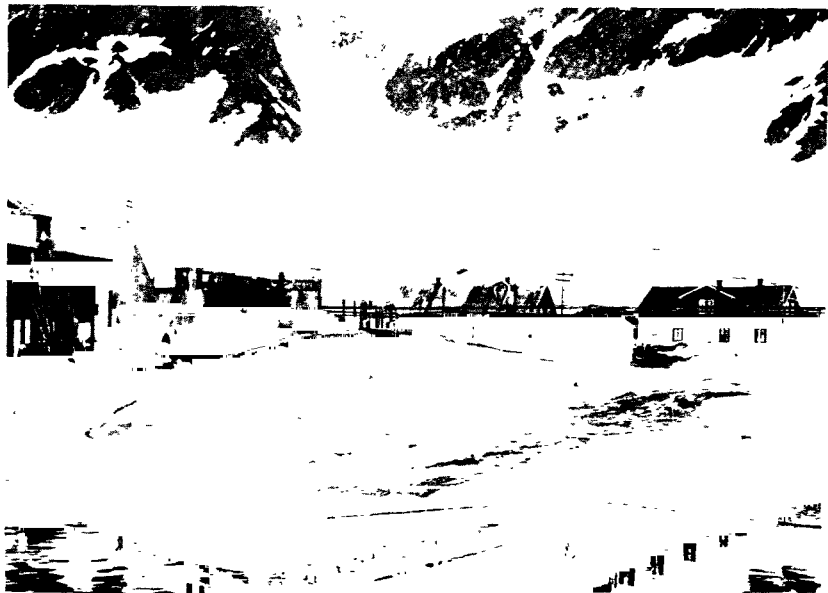
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1. SOUTHERN RIGHT WHALE.

The body is lying on its back and about half the baleen plates project outside the lip of the lower jaw. Marks on the lip and flank are caused by birds pecking the carcass. (Photograph by *Discovery* Committee.)



2. BLUE WHALE.

A specimen measuring 90 feet, on the flensing platform of an Antarctic whaling station. The lower jaw is slightly displaced. (Photograph by *Discovery* Committee.)



1. FIN WHALE.

Ventral view of a fin whale. Cuts have been made in the blubber in preparation for removal. (Photograph by *Discovery* Committee.)



2. HUMPBACK WHALE

Ventral view. The long flipper and tail fluke are visible. (Photograph by *Discovery* Committee.)

LIFE HISTORY OF THE QUETZAL¹

By ALEXANDER F. SKUTCH

[With 4 plates]

The New World, for all its wealth of feathered life, boasts no family of birds at once so large and so ornate as either the pheasants or the birds of paradise of the Old World. The trogons are perhaps the most gorgeous avian family that the Western Hemisphere possesses, although they are a group shared with the eastern world. Trogons display glittering metallic plumage in far larger expanses than any hummingbird, and the colors of the males are usually brilliant and contrasting. Most, however, are devoid of ornamental plumes. An exception is the quetzal, which in this superb family is easily first in splendor. It is certainly one of the half dozen or so most beautiful birds in the Americas, and even in this select group may deserve highest rank.

Not only is the quetzal a magnificent bird, but it is also one of the most widely known. Save possibly the scarlet macaw, this was the first Central American bird of whose existence I became aware. Like many another boy, I collected postage stamps; and an ornate Guatemalan issue, with its quetzal in red and green, was considered a collector's prize. But it gave no just idea of the true splendor of the bird. Later, when I came to travel in Guatemala, I found its image very much in evidence, in the medallion displayed on the walls of most of the public edifices and in the center of the blue and white banner. I even carried *quetzales* in my pocket and disbursed them at sundry hotels and shops; for Guatemala has named her monetary unit for her national bird, as many of the neighboring republics have named theirs for famous men. The second city of the land bears the name of this bird—Quezaltenango, the place of quetzals—but today one searches in vain for these trogons on the wind-swept plains and through the low oak woods in the vicinity of this metropolis of the West.

In selecting the quetzal as their national emblem, the Guatemalans made a more than usually felicitous choice, a creature at once native

¹ Reprinted by permission from *The Condor*, vol. 46, No. 5, pp. 213-235, September-October 1944.

of the land itself, ornate as a design, and refreshingly different from the belligerent birds, beasts, and mythological fire-breathers that adorn the coats of arms of so many other nations. And the quetzal, no less than the soaring eagle and the rampant lion, has its appropriate legend to illustrate its nobility of spirit and reflect that of the people it represents. Every Guatemalan will proudly tell you that the quetzal will die of a broken heart if deprived of freedom. I have heard of Honduran and Costa Rican quetzals that survived considerable periods of captivity; but I sincerely hope that none hatched on Guatemalan soil will ever be guilty of conduct so unworthy of the national traditions. It always makes us sad when an ugly experiment bears witness against a beautiful legend.

The quetzal is something more than the living representative of a beautiful country of the present era; its human associations stretch back into antiquity. Possibly no other feathered being of this hemisphere, the bald eagle and the turkey not excepted, has a longer history, as the philologist rather than the naturalist would use the term. This history is largely unwritten; and it is to be hoped that before long one who is at once an archeologist and an ornithologist will make good the deficiency. Still, Salvin and Godman, in the "*Biologia Centrali-Americana*," have given us some glimpse of its antique importance. The long, waving green plumes of the male quetzal's train were coveted objects of adornment of the Indian chieftains, as one may plainly see on many a modern restoration of ancient scenes. Their use was limited by law to royalty and the nobility. The male quetzals were captured alive—it is stated with corn, as bait, which I rather doubt—and after being despoiled of their proudest ornaments, released that they might grow them afresh and continue to propagate their kind. Thus the brown aborigine, later so despised and crushed into the dust, proved himself more far-sighted than the white invaders who overcame him. The bird was described by some of the early historians of the Conquest; but it soon grew so rare in all the more accessible portions of the Spanish Kingdom of Guatemala that its very existence came to be doubted in Europe, some ornithologists even classing it among the birds of fable. In the nineteenth century, it was rediscovered by Europeans; and soon its skins began to flow across the Atlantic for museums and the cabinets of collectors. This nefarious trade reached such proportions that the quetzals might well have been exterminated had not so many of them dwelt in wild mountainous regions which even today are most difficult of access and scarcely explored. Most of these trade-skins originated in the Alta Vera Paz in Guatemala.

One other legend about the quetzal seems worth repeating here, especially as it had much to do with fomenting my own desire to study the

bird in life. As often as they tell the traveler that the quetzal invariably dies in captivity, the Guatemalans volunteer the information that its nest cavity in a decaying trunk is provided with two opposite doorways, so that the male when he comes to take his turn on the eggs may enter from one side, perform his spell of incubation, then depart by the other, all without being obliged to turn around to the detriment of his gorgeous train. Few Guatemalans have actually seen the quetzal's nest, for the birds survive only in the wildest, least inhabited regions of the Republic. Osbert Salvin (*Ibis*, 1861:66) tells of a nest in what was taken to be an old woodpecker hole. It had a single doorway, and he believed that the female alone incubated.

The foregoing is, briefly, what I had been able to learn about the quetzal up to the early half of the year 1937. I had already given attention to the habits of Central American birds during seven nesting seasons, and I had learned something about the breeding habits of one more kind of trogon during each of these years. But of the quetzal I had enjoyed only fleeting glimpses on two or three occasions, in the highlands of Guatemala and Costa Rica. To complete my studies of this family, I needed observations upon its most famous and most resplendent member. I wanted to decide for myself between the conflicting accounts of its nesting; but everything I knew about trogons inclined me to believe that, in whatever kind of nest, the male shared in incubation.

I was fortunate enough to rent an unexpectedly comfortable cottage in a wild region still largely covered with forest, in which quetzals were abundant. The adequacy of the dwelling was important, for even sheltered as I was, it was at times difficult enough to withstand the depressing effects of the cold rainstorms that continued scarcely broken for weeks on end, with hardly a gleam of sunshine. The point where I studied the quetzals was at an altitude of 5,500 feet, about 2 miles below the hamlet of Vara Blanca, on the northern side of the Cordillera Central of Costa Rica, along the old trail leading from Heredia across the continental divide down through the forests to the Río Sarapiquí, an affluent of the San Juan. My period of residence there extended from July 1937 to August 1938, with less than 2 months of absence between November and January. If I did not learn more about the ways of the quetzal, it was not because of any lack of these birds in the neighborhood, but rather because a wealth of birds of other kinds offered too many temptations to divagate.

THE ENVIRONMENT

The quetzal (*Pharomachrus mocinno*) ranges through the mountains from the Mexican state of Chiapas to western Panama. In this thousand-mile stretch of territory—Central America in the proper geo-

graphic sense—there are two areas of highlands, separated by the belt of lowland that crosses the isthmus along the Río San Juan and Lake Nicaragua. As with so many other birds of corresponding range, the quetzal shows geographic variation on the two sides of the gap. The northern form (*P. m. mocinno*) is distinguished by the greater length of its upper tail coverts; it ranges from Chiapas to northern Nicaragua. The southern race (*P. m. costaricensis*) dwells in the mountain complex of Costa Rica and western Panama. Other members of the genus are South American.

The quetzal is an inhabitant of forests of the Subtropical Zone. In Costa Rica, it is most abundant between 5,000 and 9,000 feet above sea level. Occasionally it is found as low as 4,000 feet; I have a record of a single bird at this altitude, but doubt if it often ranges lower. Where forests of huge oak trees extend up to nearly 10,000 feet in the Costa Rican mountains, it is not impossible that the quetzal accompanies them, although definite records appear to be lacking. In Guatemala, farther from the Equator, the northern winter makes itself felt and the Temperate Zone replaces the Subtropical at a lower altitude. Here the quetzal does not, at least at the present time, appear to extend upward beyond 7,000 feet. The dense human population of the central highlands may well have been responsible for the bird's disappearance from the few possibly suitable forests that remain above this altitude. With one exception, all the other Central American members of the trogon family dwell at altitudes lower than the quetzal, although a few, as the Jalapa collared trogon (*Trogon collaris puella*, and *Trogon aurantiiventris*, which seems to be a mere color phase of this species) overlap its range from below. The Mexican trogon (*T. mexicanus*) is characteristic of the Temperate Zone in Guatemala and extends higher than the quetzal.

The forests in which the quetzal dwells are composed of crowded lofty trees, those that form the canopy ranging from 100 to 150 feet and even more in height. Oaks of a number of kinds occur throughout the quetzal's altitudinal range, but they are more abundant toward its upper limit, where with huge boles and spreading crowns they dominate the woodland. Alders (*Alnus acuminata*) are abundant in many places, becoming nearly as tall, although not so massive, as the oaks. But more important for the quetzals are the numerous members of the laurel family (Lauraceae), including the wild relatives of the avocado (*Persea* spp.) and species of *Nectandra* and *Ocotea*—variously called *ira* and *quizarrá* in Costa Rica, *tepeaguacate* in Guatemala—whose fruits are an important food of our birds. These forests are watered by abundant rainfall, and at all seasons they are bathed in cloud-mist much of the time. The constant moisture favors the development of an epiphytic vegetation of whose proportions one can hardly form a

conception when he knows only the forests of the North Temperate Zone, or even those of the lowland Tropics. Each larger tree upholds a mass of vegetation which must be estimated, not in pounds or in hundredweight, but in tons. In the dense covering of mosses are rooted ferns, herbs, shrubs, and even trees of fair size. Especially noteworthy are the orchids of myriad kinds, the cavendishias and related ericaceous shrubs, with their glossy leaves and heads of pink and white blossoms. The undergrowth is often dense, with tangles of slender-stemmed bamboos, ferns in bewildering variety, and shrubs and herbs, including many elegant members of the *acanthus* family and the *Gesneriaceae*.

Subtropical forest of this type appears essential to the existence of the quetzal. While the bird will often venture beyond the forest to forage and nest in adjacent clearings, it is not known to occur in districts from which the heavy woodland has been shorn. The almost total destruction of the original forest over the central plateau of Costa Rica and nearly all of the *altos* or central highlands of Guatemala is responsible for the disappearance of the quetzal from these regions, no less than the unremitting persecution of commercial plume collectors and less expert trophy hunters. But happily for the bird and those who admire it, there still exist, in the northern parts of the departments of Alta Vera Paz and El Quiché in Guatemala, but above all in Honduras and southern Costa Rica, great areas of subtropical forest on mountains so rugged and difficult of access that they must long defy the devastating invasions of man. Recent well-organized attempts at road making through some of these mountains serve merely to emphasize the difficulties of conquering them. As I write, I look over the broad, forest-mantled flanks of the Talamancan Cordillera and like to think that for many centuries they will remain the inviolate home of the quetzal, the Costa Rican bellbird, the black-faced solitaire, the Costa Rican chlorophonia, and all the birds that dwell with them in the subtropical mountains. Doubtless quetzals must continue to owe their existence more to the inaccessibility of their haunts than to human laws, which, as that decreed a dozen years or so ago in Guatemala for their protection, are usually not made until the creature they would save becomes rare almost to the vanishing point.

APPEARANCE OF THE QUETZAL

Although a formal account of the plumage of the quetzal may be found in Ridgway's "Birds of North and Middle America" and other standard works of descriptive ornithology, I shall give here, with only slight verbal changes, a word picture that I wrote in my journal on April 28, 1938, when I had the living birds daily before me: "The male is a supremely lovely bird; the most beautiful, all things con-

sidered, that I have ever seen. He owes his beauty to the intensity and arresting contrast of his coloration, the resplendent sheen and glitter of his plumage, the elegance of his ornamentation, the symmetry of his form, and the noble dignity of his carriage. His whole head and upper plumage, foreneck and chest are an intense and glittering green. His lower breast, belly and under tail coverts are of the richest crimson. The green of the chest meets the red of the breast in a line which is convex downward. The head is ornamented by up-standing bristly feathers which form a narrow, sharply ridged crest extending from the forehead to the hindhead. The bill is bright yellow, and rather smaller than that of other trogons, even those of inferior size. The glittering eye is black, and set directly among the green feathers of the face, without the white or bluish or golden orbital ring that so many trogons possess.

"The wing-quills are largely concealed by the long, loose-barbed, golden-green, plume-like feathers of the coverts, whose separated extremities, passing beyond the wings on to the sides of the bird, stand out beautifully against the crimson that shows between them. The ends of the black remiges are left uncovered by the covert-plumes and contrast with the green rump, upon the sides of which, when folded, they repose. The dark, central feathers of the tail are entirely concealed by the greatly elongated upper tail coverts, which are golden-green with blue or violet iridescence, and have loose, soft barbs. The two median and longest of these covert feathers are longer than the entire body of the bird, and extend far beyond the tip of the tail, which is of normal length. Loose and slender, they cross each other above the end of the tail, and thence diverging gradually, form a long, gracefully curving train which hangs below the bird while he perches upright on a branch and ripple gaily behind him as he flies. The outer tail feathers are pure white and contrast with the crimson belly when the bird is beheld from in front, or as he flies overhead. To complete the splendor of his attire, reflections of blue and violet play over the glittering metallic plumage of back and head, when viewed in a favorable light.

"The female quetzal is far less beautiful than her mate. She is the one female trogon I know whose upper plumage is green like the male's, instead of brown or slate-colored. Her head is dark smoky gray, sometimes slightly tinged with green, and bears no trace of the male's crest. Her bill and large eyes are black. Her back and rump are green, but less intensely so than those of the male; and the upper coverts of her wings and tail are green and elongated like his, but in less degree. The tips of the wing coverts scarcely extend beyond the margin of the folded wing, and the longest tail coverts at most but slightly exceed the length of the tail. Her chest is green; but

the breast and much of the belly are dark gray and only the lower belly and under tail coverts are red, of a shade paler than these parts of the male. The outer tail feathers, instead of being pure white, are narrowly barred with black."

HABITS AND VOICE

While perching, the quetzal, like other trogons, assumes a very upright posture, its tail directed downward or even inclined slightly forward under the perch. If alarmed, agitated, or suspicious, both sexes have the habit, widespread among trogons, of rapidly spreading the tail feathers fanwise and closing them again, sending forth flashes of white from the outer rectrices, which to one viewing the bird from the rear are usually concealed by the dark central feathers and the coverts. In quitting his perch, the male commonly drops off backward, instead of flying straight forward in the usual manner. Thereby he avoids dragging his train over the branch each time he takes wing, which would in the course of months fray it greatly through friction against the rough bark. My notes are not explicit as to whether the female, lacking the train, takes off in the same fashion; but my impression is that she does not.

The flight of the quetzal is undulatory, but less strongly so than that of some of the smaller trogons. Its method of plucking small fruits from a tree is the same as that of the other members of the family. Starting from a resting position, it darts up to a cluster of berries, seizes one in its bill, and detaches it by throwing its weight against it as it drops away, all without alighting. Such fruit-catching is spectacular with all trogons; and with the magnificently attired male quetzal it is indeed a striking display. The cottage at Vara Blanca stood on the cleared back of a narrow ridge, with forest on either slope a short way down. From the porch I sometimes watched a pair of quetzals foraging in the crown of a great *ira rosa* (*Ocotea pentagona*) that grew in the pasture on the slope to the west, its upper boughs on a level with my eyes. The birds would emerge from the forest, snatch a few of the big, green fruits in their usual dashing way, then dart down into the wooded ravine whence they had come.

From my arrival at Vara Blanca in July until the last days of February, I had attributed only a single kind of call to the quetzal. This was a loud, startled-sounding *wac-wac*, *wac-wac* that they often voiced in flight. The call bears a certain resemblance to the notes of alarm of the smaller trogons, most of which have a startled, cackling character, but are less powerful than the corresponding utterance of the quetzal. But in late February, as the mating season approached, I began to hear notes of a very distinct kind. During March, the

quetzals called much; and it became clear to me that they had a rather varied vocabulary, including sounds of rare beauty. They were most vocal in calm, cloud-veiled dawns, and late on misty afternoons; in bright weather they called less, and on windy days rarely broke silence. Their notes reminded me somewhat of the utterances of the clearer-voiced of the small trogons, as the Mexican, Jalapa, gartered (*Trogon violaceus*), and graceful (*Trogon rufus tenellus*), yet were quite distinct from any of these. The quetzal's voice, at its best, is softer and at the same time deeper, fuller and more powerful than that of any other trogon I know. The notes are not distinctly separated, but are slurred and run into each other, producing a flow of mellow harmony. Even as the quetzal surpasses his kindred trogons in splendor of plumage, so he excels them in mellowness of voice. The female, on rare occasions, was heard to utter a clear-voiced call resembling that of the male, but in far weaker, more subdued tones.

At times, especially at the outset of the season of nesting, the quetzals voiced notes of a whining, complaining character, which appeared to be mating calls. I could not then make sure whether both sexes used this sound or only one, nor which it was; but I sometimes heard it when they were together at the edge of the forest. Later, when they were incubating, both male and female would deliver nasal or whining notes of a rather similar character as each came to relieve the other on the nest. In May I became aware of an utterance very distinct from all these, a high, soprano, sliding *whooo*, not especially loud—a surprising performance which, when first heard, I was inclined to attribute to a mammal rather than a bird.

The flight display of the male quetzal is accompanied by an utterance all its own that is obviously a modification of the flight note already described. From time to time, in March, April, May, June, and July, the male rises on wing well above the treetops, circles around in the air, then descends again into the shelter of the foliage. His flight on these sallies is strong, swift, and direct, often with little of the usual undulatory motion; but if he goes very high, it may at the end become pronouncedly wavy and jerky, suggesting that he has about reached the limit of his endurance. As he soars up into the air, he shouts loudly a phrase which at various times I set down as *wac-wac*, *wac-wac*, *wac-wac*, but as often *very-good*, *very-good*, *very-good*.

On a number of occasions, I saw the male, when relieved of his long turn on the eggs by the arrival of his mate, set forth directly from the doorway of the nest on one of these flights, calling loudly as he went. Such aerial sallies are not rare among birds of open fields and low thickets, as the skylark and the bobolink, or, to take closer neighbors of the quetzal, Baird's yellowthroat (*Geothlypis semiflava*), the streaked saltator (*Saltator albicollis*) and Lawrence's elaenia (*Elaenia chiri-*

quensis) ; but they are decidedly uncommon among denizens of heavy forest. I know no other trogon, nor any bird of the tropical rain-forest at whatever altitude, which indulges in such exercises. The gliding flights of the guans (*Penelope purpurascens* and *Chamaepetes unicolor*), in the midst of which they produce drumming sounds with their wings, are of quite distinct character.

One afternoon in early March, I watched in a narrow clearing in the forest, in the midst of which stood a tall decaying trunk, where a pair of quetzals were interested in a possible nest site. As the sun sank low, I heard mingled mellow calls and whines float out of the bordering woodland. Presently the male rushed out into the clearing, flying in a wild, dashing, irregular fashion, his long, loose, green wing-covert and tail-covert plumes vibrating madly, shouting *wac-wac-wac-wac way-ho way-ho*. This appeared to be a distinct kind of flight display, accompanied by a somewhat altered call.

I have heard tell of flocks of quetzals in the Costa Rican highlands, but have never seen such an aggregation. When I arrived at Vara Blanca in early July, the quetzals were probably still nesting, although I found no nests until the following year. I saw a number, chiefly single individuals, during that month; but in August and early September I met none, and I began to suspect they had migrated from the region. But in the second fortnight of September I encountered two. Yet from August to the following February they were very little in evidence; and the few that I saw were mostly silent and alone. It was not until late February or early March that quetzals appeared to become abundant in the vicinity. It is not impossible that there had been an influx of individuals into the locality, but I suspect that their apparent increase in number resulted from their greater activity, and above all, the more frequent use of their voices. The quetzal, for all his glittering splendor, is not easy to detect as he perches quietly among lofty boughs smothered in air plants.

By the first week of March the birds seemed quite generally to have paired. Once I saw four flying through the shady pasture together, but these appeared to be rivals rather than members of a flock. Possibly the quetzals at times gather in numbers about a tree that offers an abundance of fruit, and in the mating season, several rival males may call from the same part of the forest, as with other trogons. Nevertheless I doubt if they form true flocks, which appear not to exist among the American members of the family.

THE NEST AND EGGS

The quetzal nests in a hole in a decaying trunk, upright or slightly leaning. This may be situated within the forest, or in an adjoining clearing, sometimes as much as a hundred yards from the woodland

border. The six nests I found in 1938 ranged from 14 to an estimated 60 feet in height above the ground. In size and form the cavity closely resembles that of the larger woodpeckers, as the Guatemalan ivory-bill (*Scapanus guatemalensis*) or the pileated woodpecker (*Ceophloeus lineatus*). The single entrance at the top is irregularly circular, about 4 to 4½ inches in diameter. One hole which appeared to be freshly carved—the man who showed it to me said he had seen the birds at work—extended to the depth of only 4½ inches below the lower edge of the doorway. This contained eggs, although they had been broken before I saw the nest. A second nest, which was very old and weathered when the quetzals began to use it, extended 11 inches below the sill of the doorway and was 6 inches in width. Although the other nests were inaccessible, I believe that most of them had a depth well in excess of the 4½ inches of the shallow one I measured; this opinion is based on the positions of the birds when incubating or feeding nestlings within them.

In form, the quetzal's cavity is quite distinct from that of the other trogons' nests I have seen (Skutch, Auk, vol. 59, pp. 341-363, 1942). Some trogons lay their eggs in cavities they carve in termites' or wasps' nests, others in decaying wood. But of the other trogons that dig into wood, the Mexican, Jalapa, and graceful trogons are content with shallow niches that leave much of the incubating bird exposed to outer view. Baird's trogon (*Trogon strigilatus bairdii*) carves deep into the trunk, forming a completely enclosed chamber entered through an obliquely ascending tube.

The trunk in which the quetzal nests is sometimes in the last stages of decay. One nest cavity was situated at a height of 30 feet in the top of a massive but very rotten stub standing in a pasture. Since I had not at the time of finding this seen any lower nest, I made a determined effort to glimpse its contents, standing on the next-to-highest rung of a tall ladder and holding a mirror at the doorway, still above my head, while the interior was illuminated by an electric bulb. While I was engaged in this foolhardy venture, a visiting naturalist looked on and prophesied disaster. I could see nothing, yet dared not step upon the topmost rung and depend for support upon the trunk alone. But later, after the nestlings had flown, we put a rope about this trunk, cut some of the supporting prop roots, and pulled it over; for I wished to examine and measure the cavity. Upon striking the ground, the upper portion fell into a formless heap of rotten wood. It was not even possible to distinguish the point where the chamber had been! We had a similar experience with a trunk containing an empty 18-foot-high nest, which we pushed over in the forest for examination. After it struck the ground, there was nothing left to examine. Not infrequently, a woodpecker hole will remain perfectly intact and

sound after falling from twice or thrice the height of these quetzals' nests. The lowest nest chamber, to which I devoted so much attention in July and August, was covered in front only by the bark of the decaying stump, a large sheet of which seemed on the point of falling away and exposing the eggs. I thought it prudent to hold it in place by encircling the trunk with cord.

I did not in any instance see quetzals actually carve their nest chamber. The three nests in which first broods were raised seemed old and weathered when I found them. But the shallow cavity already mentioned gave every appearance of having been freshly carved in decaying wood still considerably sounder than that which collapsed into a heap when it fell. This nest was shown to me by Don Moises Larra, in front of whose cabin it stood. He told me that he had seen the male and female quetzals taking turns at carving it out. This, of course, is the way in which most if not all kinds of trogons make their nests.

Early in March, a pair was interested in a tall, branchless, decaying trunk that stood in a pasture near the edge of the forest. While I watched, the female clung upright in front of an old, long-abandoned woodpecker hole near the top of the stub. She spread her tail and braced it against the trunk, revealing the white outer feathers narrowly barred with black. Clinging so, she bit at the decaying wood about the rim of the doorway, tearing off fairly large flakes of the soft substance and letting them drop to the ground. She continued this occupation for a minute or less, and while she was so engaged I heard soft, full notes, but could not make sure whether they arose from her or from the male who perched nearby. Upon dropping away from the tree, she rejoined her waiting mate and both returned to the forest. Finally, this pair nested in an old hole in the top of another dead trunk not far off.

At Vara Blanca I found no breeding woodpecker whose hole could accommodate, without alterations, a bird as large as the quetzal. The hairy woodpecker (*Dryobates villosus*), acorn woodpecker (*Balanosphyra formicivora*), green woodpecker (*Piculus rubiginosus*) and oleaginous woodpecker (*Veniliornis oleaginus*) were the only resident species—all considerably smaller than the quetzal. Likewise, the prong-billed barbet (*Dicrorhynchus frantzii*), whose nest cavity closely resembles a woodpecker hole, is not nearly so large as the quetzal. Before a quetzal could nest in a hole carved by any of these five species, it would have to enlarge it, especially the doorway. I believe that this is what the pair I watched had started to do, but thereafter something was found that could be made to serve with less effort. Whenever an old hole of their own remains from a former year, still sound enough to contain their eggs and even if in a precarious state of decay, these trogons appear to use it again. When still available, the

cavity that served for the first brood is made to do duty for the second after the bottom is cleaned out. When they can find nothing ready made, the quetzals appear to carve their cavity from the beginning, in soft, decaying wood, in the manner of other trogons. At lower elevations, where their range overlaps that of the ivory-billed or pileated woodpeckers, the quetzals may find cavities of adequate size all ready for them; but over most of their range, they can hardly avoid a certain amount of hole carving.

The quetzal's eggs rest upon the loose fragments of wood in the bottom of the cavity, for no soft lining is taken in. I saw only two sets, one in May and the other in June. The eggs in the May nest had been broken before I was taken to see them. Feathers scattered about pointed to the work of some predatory animal. There had been at least two eggs, light blue in color. The one still whole enough to be measured was 38.9×30.2 mm. The June nest also contained two light blue eggs, which I did not deem it prudent to remove from their deep, rather dilapidated cavity. In a high, inaccessible nest to which I devoted considerable attention, at least two fledglings were reared.

INCUBATION

On April 6, 1938, I wrote in my journal: "Two mornings past, I saw a female quetzal, then a male (of the pair, I believe, that had earlier begun to enlarge the entrance of the old woodpecker hole in a neighboring trunk) cling upright in front of a large, round hole at the very top of a tall, massive and much decayed trunk which stands at the edge of the forest at the lower end of the pasture. The hole is to all appearances an old one, the wood about its rim much weathered; and I have passed beneath the trunk so often that I think I should have seen the quetzals at work had they made it recently. Each, after clinging a few seconds there, flew back into the forest.

"Yesterday morning, when I passed by, I saw the male sitting in the cavity. *He sat facing outward, with his head and shoulders projecting through the aperture.* His tail was at the back of the cavity, but *one of the long feathers of the train was bent double and projected through the entrance,* above the bird's left shoulder. Where, then, is the Guatemalan story of the nesting cavity with two entrances, so that the male quetzal's tail can project through the rear one? Or the Costa Rican version that the bird sits in the nest head inside and tail dangling from the single doorway?

"When the quetzal noticed me beneath him, he flew forth from the hole. I did not deem it prudent to return later in the day. This morning, at 6 o'clock, I saw the female enter the hole; but at 10 o'clock it was unoccupied. Apparently the birds have not yet begun to incubate."

On April 8, the male quetzal was in the nest at 7:40 in the morning, but he flew out and rose above the treetops as I approached. That same afternoon, at 2:20, for the first time I found him actually covering the eggs. I approached very quietly so that he did not hear me and look out. All that I could see of him was the ends of the two long feathers of his train. These, bent forward and pressed against the upper edge of the doorway, projected the better part of a foot into the open. Had the trunk been covered with epiphytes, as it would have been if it had not been too rotten and crumbly on the outside to afford them a root-hold, the projecting feathers might have been mistaken for the green fronds of a fern.

On subsequent visits to this and two other nests I found a little later, I learned that I could always detect from a distance the presence of the male quetzal in the nest by the projecting ends of these two long central tail coverts. They extended from 6 inches to a foot into the outer air and waved gracefully in the light April breezes. Although all the remainder of the bird was quite concealed in the bottom of the deep cavity, and I could not actually see the position in which he covered the eggs, the visible portions of these plumes indicated that he sat facing forward, with his tail held upright against the rear wall. This is actually the posture assumed in incubation by the Mexican, Jalapa, and graceful trogons, which are readily seen as they sit in their shallow cavities. But the male quetzal's long train continued upward, then bent outward, and pressed against the upper side of the doorway which held the flexed ends in an almost horizontal position.

It was early evident that both sexes took substantial shares in the incubation of the eggs. In order to learn in more detail how they divided the day between them, I devoted about 58 hours to watching the nests during incubation. Records covering all hours of the day were made while my first pair incubated both their first and second sets of eggs and while my second pair were hatching out their second brood. I usually made continuous vigils of from 5 to 7 hours, beginning in the middle of the day, watching until nightfall, and when the weather was not too adverse, resuming the vigil at the following dawn and continuing to the middle of the day. In addition to these long records, a number of briefer observations were made in order to time the morning and evening nest-relief. Although the first nest was high, I watched it from concealment. But the pair at the second, low nest gradually grew so accustomed to my presence that they showed no concern when I sat quietly beneath a tree in view of them. While feeding their nestlings they finally became so tame that I was able to photograph them at the nest, at close range, without using any form of concealment.

The records for all three nestings showed substantial similarity in the division of the day between the male and female. There was a

basic pattern of incubation; but this was subject to considerable variation from nest to nest, and on different days at the same nest. The fundamental pattern was this: the female incubated every night and during the middle of the day; the male took a long turn on the eggs in both the morning and afternoon. Each sex was responsible for the nest twice during the cycle of 24 hours. But their periods of responsibility might be interrupted by brief absences, during which the eggs were left unattended. There is no reason to suppose that the female did not sleep continuously in the nest through the night; for the quetzal, like other trogons, appears to be strictly diurnal in its activity. The variations in the daily program we shall now consider.

The male quetzal began his morning session at times ranging from 5:52 to 7:27 a. m.; but he inclined toward the former hour as the eggs neared the point of hatching. If he appeared early, the female might continue her long night session until he arrived to replace her. But usually she flew out still earlier, from 5:35 to 6:00, and if her mate did not appear fairly promptly, she returned in from 5 to 14 minutes to await him on the eggs. The male's period in charge of the eggs during the morning was of variable duration; the shortest that I timed lasted 2 hours and 13 minutes and was continuous; the longest was for 4 hours and 30 minutes, broken by one spontaneous absence of 2 minutes, and another of 21 minutes when he was frightened from the nest by a passerby. One male took charge of a nest for 3 hours and 15 minutes, with three short recesses totaling 38 minutes.

The female's midday period began at times varying from 8:21 to after 11:10 a. m. Since I usually watched from midday to nightfall and from dawn to midday, I timed in full only two periods. One began at 9:35 a. m. and lasted until 1:14 p. m., 3 hours and 39 minutes, broken by a single recess of 7 minutes, from 11:03 to 11:10 a. m. The second, at the same nest, began at 8:21 a. m. and continued until 12:49 p. m., 4 hours and 28 minutes, interrupted only by a brief absence of 11 minutes, from 12:23 to 12:34.

The male's afternoon session began at times varying from 12:53 to 4:36 p. m. Four sessions that I timed lasted 52 minutes, 1 hour and 9 minutes, 2 hours, and 3 hours and 3 minutes. All were uninterrupted. Each of the two males is to be credited with one long and one short session.

On a wet, mist-shrouded afternoon soon after her eggs were laid, the female at nest 1 resumed charge at 2:14 p. m. and remained in sole charge until the following morning, with brief recesses from 4:18 to 4:27, and from 5:48 to 5:58 p. m. But this was unusual. As a rule, the male sat until about 5:30 p. m., then left the eggs uncovered until the female returned for the night, from 5 to 41 minutes later. The female at nest 1 arrived consistently earlier than her neighbor at

nest 2. Her two evening returns which I witnessed took place at 5:30 and 5:53. The other female entered at 6:09, 6:01 and 6:07, when the daylight was growing faint.

The noon-to-noon record of the first nest shows that the male incubated a total of 7 hours; that of the second nest credits him with 6 hours and 7 minutes, out of approximately 13 hours of total daily activity.

Compared with other, smaller trogons, the quetzal sits for brief periods. The fundamental pattern of incubation among trogons is the same as for pigeons; there are only two shifts in each 24-hour cycle, the male sitting through the middle of the day, the female from the middle or late afternoon until the early half of the following morning. This is exemplified by my records of the black-headed (*Trogon m. mellanocephalus*), graceful, Jalapa, and Baird's trogons. Because I usually begin or end my observations at midday, I have not often watched through the complete session of a male trogon of the smaller kinds. But once a male Baird's trogon sat for exactly 6 hours, without once showing his head in the doorway of his well-enclosed nest; he and his mate kept the eggs continuously covered. So did a pair of little graceful trogons in Panamá, the noon-to-noon record pointing to uninterrupted incubation by the male for about 8 hours. The male black-headed trogon, sitting in his territory, takes sessions of corresponding length; but he and his mate do not always wait for each other before going off to hunt food.

In contrast to the female quetzal's impatience to depart from the nest in the early morning, I have known a female Mexican trogon to extend her night session through the entire morning and until 1:10 in the afternoon, never once leaving for food. A female Jalapa trogon sat continuously from 4:51 p. m. until 11:27 next morning, refusing her mate's offer to relieve her at the unusually early hour of 7 a. m. Why the quetzal should incubate so much less assiduously than its smaller cousins is not clear. Most trogons nest in lower and warmer regions. The Mexican trogons dwelt at a far greater altitude; but all were not so patient in incubation as the female to which we have referred. With other families, as with the trogons, size has little to do with the length of a bird's sessions on the eggs.

Upon arriving to replace the mate on the nest, both male and female quetzal would often, but by no means always, utter whining or nasal notes while perching nearby. At the same time they flash their white outer tail feathers with a momentary fanning of the rectrices, then twitch the tail upward—a typical trogon gesture. Sometimes the partner in the nest would come forth upon hearing the summons, but again it might disregard them. Its response doubtless depended upon how eager it was to leave. If the bird in the nest did not come forth,

the one arriving might fly up in front of the doorway, but always veered aside and went to a perch when it saw that the hole was occupied. This move usually caused the other to quit the eggs. At times, the new arrival would fly up to the doorway in this fashion with no previous announcement of its presence. Each of the males, but especially that of the second pair, was sometimes guilty of calling his mate from the eggs, then flying off with her as she departed, leaving the nest unattended until either he or she returned to take charge of them. The female more rarely did the same thing. Thus there was no set ceremony of nest relief. Less closely synchronized than mated birds of many other kinds, one of the pair might come before the mate was ready to go; or one would go before the other was ready to come. Yet in spite of inconsistencies, they managed to get through their three-shift day without leaving the eggs exposed for many minutes. After incubation had well begun, the nest was rarely left unattended for more than half an hour at a stretch, although once both members of the pair at nest 1 were absent for 67 minutes, and on another occasion for 51 minutes.

For many kinds of trogons, the entry into the nest is a very protracted procedure. They cling before the doorway, peering cautiously from side to side, often for several minutes, before slipping inside. If they espy something that excites their suspicion, they dart away to return a little later and go through the lengthy performance again. The quetzals entered in a less hesitant fashion, often hardly delaying in front of the doorway, or at most making only a brief survey from this position.

Upon quitting the nest, the male, as already recorded, would sometimes rise into the air in a flight display, shouting as he went. I saw one of the males do this six times, the other thrice. These spectacular flights were made at any hour of the day; one of the males left the nest in this manner when his mate relieved him at sunset. Even when frightened from the nest by a passing man, the reckless bird might soar up and make himself conspicuous to all the neighborhood. Or at times he would give loud calls as he flew off, without rising above the trees.

While I watched them, the quetzals were not often called upon to drive intruders from the vicinity of their nests. On April 10, not long after they began to incubate, male and female of my first pair joined in giving chase to a trespassing female of their kind. Later, I saw this male pursue a blue-throated toucanet (*Aulacorhynchus caeruleogularis*), which would have enjoyed eating their eggs, and twice a tityra (*Tityra semifasciata*), which seemed to be prospecting for a nest cavity in the same trunk. Another pair of quetzals was worried by a pair of sulphur-bellied flycatchers (*Myiodynastes luteiventris*)

building a nest near their own. Once while the male quetzal was brooding the nestlings, a strange female flew to the doorway, with no food visible in her bill. One of the flycatchers gave chase to her, and the quetzal, emerging from the nest, also darted at her, but without touching her. She flew directly away and I saw her no more.

Only at the second nest of my second pair of quetzals could I actually see the eggs and determine the period of incubation. The nest was in a low, rotting stub in a shady pasture beside a little-used pathway. I feared betraying its position to passers-by and through an excess of caution did not set up a ladder and look in with a mirror until I was sure that incubation had begun. At this late nest the birds began to incubate on June 24, or possibly even on the 23d, and the nestlings hatched on July 11, giving an incubation period of 17 or 18 days. This agrees rather closely with the periods available for other trogons: 18 or 19 for the Mexican trogon, 19 for the black-headed trogon, 18 for the graceful trogon.

CARE AND DEVELOPMENT OF NESTLINGS

Like other newly hatched trogon nestlings, those of the quetzal bore no vestige of down upon their pink skin. Their eyes were tightly closed. Each bore a prominent white egg tooth near the tip of the upper mandible, which was slightly shorter than the lower. Their heels were studded with the short, papillate protuberances typical of nestlings that grow up in a nursery with an uncarpeted floor. When I first saw the two newly hatched nestlings, only a few fragments of the blue egg shells remained on the bottom of the nest.

During their first few days of life, the young quetzals were brooded much of the time. They were nourished almost if not quite exclusively with small insects; it was not until later that fruits became an important element in their diet. The parents at first kept the nest perfectly clean, removing all the droppings, which apparently they swallowed, for I saw none carried away in their bills. On the nestlings' fourth morning, I heard their mother scraping and scratching in the nest, doubtless to clean it out. This attention to sanitation was eventually to be relaxed. Still, quetzals are considerably in advance of their relatives in this respect, for the Mexican trogons, graceful trogons, and Jalapa trogons that I studied did not even remove the empty egg shells and the bottom of their nests soon became foul.

When the nestling quetzals were 2 days old, the sheaths of both their contour and flight feathers began to push through their pink skin. At 4 days, there was slight change, save that the nestlings were considerably larger and their feather sheaths somewhat longer. When they were 5 days old, their eyelids began to separate. At 8 days, they could open their eyes, but most of the time rested with the

eyelids closed. On the seventh day after hatching the contour feathers of the body were breaking from the ends of their sheaths, but not those of the head. The young were 10 days old before the flight plumes of the wings and tail began to push out from the tips of the sheaths, a day after the wing coverts had reached the same stage. The bill and feet were now becoming blackish.

At this stage of development, the young quetzals always rested side by side on the bottom of their nest with their heads supported against the side wall and their bills pointing almost straight upward. They did not appear to be comfortable unless their heads were in this position, for even when removed from the nest and placed where they could find no chin-support, they held them turned abruptly upward in this fashion. From time to time, when they appeared to be hungry, they stretched up their necks and at the same time opened their mouths and sharply closed them again, making a snap. Evidently, like young motmots and woodpeckers, they took food from their parents in this harsh, abrupt fashion, instead of holding their mouths passively open for the morsel to be placed in it in the manner of passerine birds.

Up to their tenth day, the young quetzals were nourished almost entirely with animal food—indeed, I had not yet seen the parents bring them a fruit. On their eighth morning I was present when their mother came with a golden beetle (*Plusiotis aurigans*) about an inch in length. These coleopterans are certainly the most splendid I have ever seen; they are among beetles what the quetzal is among birds.

When the nestling quetzals were 11 days old, buffy spots began to appear on their wing coverts. When they attained the age of 2 weeks, their bodies were well clothed with feathers so long as they kept their wings folded. But the feathers of their heads had only the day before begun to escape the horny sheaths. The contrast between the well-clothed body and naked head was striking, and gave the little quetzals a somewhat vulturine aspect. On their fourteenth day they were photographed for the first time.

From this age onward, fruits, especially those of the laurel family, became an increasingly important constituent in the diet of the nestlings, and the large regurgitated seeds began to accumulate beneath them in the nest where the parents could not easily reach them for removal. Still, they had kept the nest sanitary for almost as long as young black-headed and Mexican trogons remain in their uncleaned nurseries.

When the young quetzals were 16 days old, their mother began to behave in a most unaccountable fashion. She ceased to brood them during the night, although they seemed scarcely old enough to be left

uncovered in that inclement weather, and by day she fed them less and less. In nearly 5 hours on their seventeenth day she came only thrice with food. On two of these occasions, she waited dully in the *poró* (*Erythrina*) tree in front of the nest, holding the morsel in her bill, until her mate arrived with food, and only then, as though stimulated by his example, did she go to the nest to deliver what she had brought. Even the preceding day, she had delayed nearly an hour, holding a green fruit until the arrival of the male caused her to take it into the nest. After this, I did not again see her in the vicinity.

To the male quetzal, then, fell the whole duty of attending the two nestlings during their last 5 or 6 days in the low hole. With his plumage showing unmistakable signs of his strenuous activities and the long feathers of his train broken off short, he was indeed an Apollo in the service of King Admetus. He no longer brooded; but the young birds' cloak of feathers made this unnecessary now. Nor did he clean out the nest. As a result the growing accumulation of big, regurgitated seeds and other waste matter slowly raised the level of the floor and the little quetzals stood each day higher in the nursery, nearer the doorway, where it was easier for them to reach up for their food.

From the first, the male quetzal had been a constant provider of food at this nest. Still, he did not feed very often; infrequent feedings are the rule among trogons. On the nestlings' seventeenth morning, he fed the two seven times during $4\frac{3}{4}$ hours. Sometimes he would bring one article of food in his bill, pass this to a nestling, then return to a convenient perch and regurgitate a fruit, which in turn was taken to the nest. The preceding day, for the first time, I had seen the parents pass food to the nestlings through the doorway without themselves going in. Now they regularly (the mother until she ceased to feed) delivered the meals while they clung in front of the entrance (see pl. 3) and did not pass through it unless the nestlings were very sluggish about taking nourishment. When hungry, the young jumped or climbed to the doorway, where from in front I could glimpse them momentarily at the instant when they were fed. Their higher floor, as well as their increased size and strength, made this feat possible. The little birds now uttered low, soft whistles as they awaited their meals.

On the nineteenth day I again watched this nest for 3 hours. From 6 to 9 o'clock the male made only seven separate visits to the vicinity of the nest. But on three occasions he rested in a neighboring tree after he had delivered the article he brought in his bill, there regurgitated a fruit, then went to the nest to deliver this, making 10 feedings in all. This was not many, but he brought each time such substantial portions, always big fruits and frequently lizards, that the young appetites were soon satisfied. Already at half-past seven

the nestlings were sluggish in taking what their father offered them. When hungry, they would appear in the doorway and snatch the food in a trice; but when satiated they remained in the bottom of the chamber, making a low sizzling noise as nourishment was presented to them. Then the male would enter and coax them to swallow what he had brought. But even when he went inside, he was not always successful in delivering the morsel. He would emerge, fly to a neighboring tree, and rest there, patiently holding the object in his bill for many minutes, while the digestive juices of his nestlings acted upon earlier contributions. After a while he would go again to the nest with the same article of food, and at length when the nestlings' hunger had reasserted itself, he would succeed in giving it to one of them.

Perhaps it will be of interest to record here the food of the two 19-day-old quetzals. From 6 to 9 o'clock on the morning of July 30, 1938, the male brought them the following in sequence: a big green fruit brought in his bill, and another in his throat; a small lizard; a small lizard; a big green fruit in the bill and another in the throat; an unrecognized object, which the nestlings were very sluggish in taking; a lizard; and a larva. After delivering the last item, he regurgitated a fruit, which he offered repeatedly over a period of 20 minutes before a nestling found room for it.

Altogether, the diet of the young quetzals, which reflected that of their parents, was surprisingly varied. The edible objects I saw taken into this and other nests included; insects of numerous kinds, often green and of fair size, the most easily recognized of which were the golden beetle (*Plusiotis aurigans*) and even more numerous greenish-gold beetles of somewhat larger size (*P. boucardi*) [for the identification of these beetles I am indebted to C. H. Lankester]; green larvae; small green and yellow frogs; small lizards; small land snails, the regurgitated shells of which were found in the bottom of the nest; the hard, big-seeded, green-skinned fruits of the *ira rosa* (*Ocotea pentagona*) and other lauraceous trees. These last are structurally similar to the avocado but of course are very much smaller. They became increasingly prominent in the diet as the nestlings grew older. Other trogons I have studied brought few or no fruits to their nestlings; this was true even of the Baird's trogon whose offspring lingered in the nest longer than these two quetzals. Yet the adults of most species include at least some fruit in their diet.

The feeding of the young quetzals by their father alone during their last days in the nest is not without parallel in my experience with trogons. Last year, a male Baird's trogon seemed to be in sole charge of the nestlings from the time they were a few days old. One perished early; but the second lived to fly from the nest, practically

reared by its father. In this instance, I saw no evidence of gradually waning interest on the part of the mother; it seemed that she met some accident.

THE JUVENAL PLUMAGE

The course of feathering of the nestling quetzals and their partial change in color during their final week in the nest was most interesting. When we last glimpsed them, they were 2 weeks old and fairly well clothed, except for their heads, so long as they kept their wings folded; this they did habitually at this age. Their upper plumage was then generally of a dull blackish color, relieved only by the buffy spots on the wing coverts which had become evident a few days earlier. But from the age of 2 weeks onward, green became increasingly evident in their plumage. This change in coloration was accomplished by the overlaying of the dull early plumage by brighter feathers of subsequent development.

The feathers of the anterior part of the dorsal tract lagged far behind those of the posterior portion of the same tract. Long after the latter had broken from their sheaths and spread over the surrounding bare skin, the anterior feathers of this tract remained tightly enclosed. Only when the young quetzals were 16 days of age did the tips of these feathers of tardy development begin to peep forth from the ends of their sheaths. They were golden green in striking contrast to the plumage that surrounded them. At the age of 18 days, green-tipped feathers were becoming evident among the scapulars, long after the blackish feathers in the same region had expanded. Green tips then began to push forth from the sheaths on the sides of the neck. A little later, the two green central tail coverts first became evident. Only on the nestlings' twenty-third day did I notice that green feather-tips were emerging from the lateral sheaths of the posterior half of the middorsal tract, a full 2 weeks after the neighboring, centrally located, blackish feathers had begun to expand. Green feathers were also just beginning to appear on the foreneck. Whereas the blackish contour feathers of early development were loose and fluffy, the green-tipped feathers of tardy appearance had firmer, more cohesive webs. The new feathers on the center of the back were a beautiful golden green; but their concealed basal portions were blackish, like the whole length of the early down feathers.

Thus, at the time of their departure from the nest, the young quetzals wore a motley garb, blackish, brown, buff, and green, but with the last-named color giving promise soon to overshadow all the others. The crown was dark brown, the hind part of the head brown of a lighter shade. There were dull green feathers on the lores and around the eyes. The sides of the neck and upper back were golden green. The

lower back and rump were dull black, but with green feathers coming in. The two central tail coverts were green, with black tips and brown subterminal spots; the remaining upper tail coverts were dull black, with a brown subterminal spot on the next to the middle pair. The tail feathers were still very short, but so far as visible the six central rectrices were dull black, whereas the outer three on each side had white vanes and black shafts. The wing plumes likewise were dull black, with buffy outer margins on all but the outermost, these becoming gradually more prominent on the inner secondaries. The wing coverts were black, variously margined with buff, except on the lesser coverts and the greater coverts of the primaries.

Turning to the under parts, the chin and throat were tawny buff, with some green feathers just sprouting in on the foreneck. The breast was buff with scattered green-tipped feathers, the flanks paler buff, and the center of the abdomen nearly white. The bill was black, the irides brown, and the feet plumbeous.

These two fledglings, of unknown sex, appeared very much the same as others I saw at a greater distance. Although they resembled neither parent, they were most like the female, from which they differed most conspicuously in the far smaller amount of visible green, the lighter color of the chest and upper abdomen, the absence of red on the belly and under tail coverts, and in many other less conspicuous particulars.

It is instructive to compare the rate of feathering of the quetzal with that of other trogons. Baird's trogon offers the most illuminating comparison, since it has an approximately equal period of nest life. The feathering of the young quetzals began on their seventh day and by their fourteenth they were well covered. But at the age of 12 days, the nestling Baird's trogon of the lowlands is still in pinfeathers. A day later, these begin to ravel off at the ends, exposing the true plumage. By its sixteenth day, the nestling is well clothed. Thus it is covered with feathers only a day or two later than the quetzal; but the shedding of the horny sheaths begins far later and is a much more rapid process. The same earlier escape of the feathers from their sheaths is evident in the Mexican trogon of the highlands as compared with the black-headed trogon of the lowlands. The contour feathers of the Mexican trogon begin to expand at the age of a week and the little birds are well feathered when 12 days old. When 2 weeks old, young black-headed trogons bristle like porcupines with their long, unbroken pinfeathers; then a marvelously rapid transformation occurs and 2 days later they are well clothed and ready to fly from the nest.

A similar acceleration of feathering in a cooler climate is revealed by the comparison of the highland blue-throated motmot (*Aspatha gularis*) with the turquoise-browed motmot (*Eumomota supercilialis*)

of the lowlands. During the month it remains in the burrow, the nestling blue-throated motmot changes its color even more completely than the quetzal. At the age of 10 days, the little motmot, hatched naked, is already practically covered with loose, fluffy down, dark gray on the upper parts and tawny on the sides and flanks. When it is 4 weeks old, its gray and tawny feathers are all covered over and concealed by green ones that develop more tardily. On quitting the nest, the young motmot closely resembles its parents, which are not to be distinguished from each other. The exact details of this change of coloration are slightly different in the motmot and the quetzal; but the general process of overlaying the dull feathers of precocious development with bright ones that expand later is the same in both. The turquoise-browed motmot of the hot regions undergoes no such alteration. The feathers do not begin to expand until about the twelfth day, and the nestlings in developing plumage at once display all the delicate beauty of the adults. I am familiar with no other bird, quite naked at birth, that changes the coloration of its plumage in this way during the period it remains in the nest. But it seems possible that in other tropical species which begin to acquire the adult colors soon after quitting the nest a similar process may occur.

Since coloration in itself can be of no importance to the safety of a motmot in its nursery at the end of a long, dark tunnel, and is probably of slight account with a quetzal in a deep cavity in a trunk, one wonders why the nestlings do not array themselves in their brightest hues at the very outset. It seems important to these highland nestlings that they early acquire a downy vesture to protect them from the cold in their covered nurseries; but at the same time they guard their feathers of firmer texture from wear, keeping them enclosed within the horny sheaths until the date approaches when they will be needed; for upon quitting the nest, both the quetzal and the blue-throated motmot enter a rainy world. The contour feathers of firm texture, which are not needed until later, are those which bear the green color. The change of coloration while in the nest appears to be incidental, and not in itself of consequence, save as an indicator of other alterations.

DEPARTURE OF THE NESTLINGS

On the morning of August 1, when the young quetzals were 3 weeks old, I for the first time saw one of them stand on the sill of the doorway; it looked out for a few minutes after the father had given it food. Two days later, I removed one of the young from its nursery and placed it on a mossy log beside me while I wrote a description of its plumage. At first it made no attempt to fly. (Neither of the nestlings had tried to use its wing on past occasions when taken from the

nest.) But after standing quietly beside me for a time, it suddenly took to the air and flew about 25 feet in a horizontal course, coming to rest upon another fallen log. The father, who had been watching us from the *poró* tree in front of the nest, began to follow as soon as it began to move and darted down to alight close beside it on the log. After a minute here, he moved to a low perch a little beyond. Then I approached to recover the nestling, which made no effort to escape me.

After completing the description of its plumage, I took up the young quetzal to return it to the nest. I found the other in the doorway, looking out. As I mounted the ladder toward it, the bird flew forth and down the slope in front of the nest. On this its first flight it covered about 150 feet in a slightly descending course, and came to rest about 25 feet above the ground in a small *yos* tree. It flew well but slowly. The father, who meanwhile had returned to the *poró* tree in front of the nest, darted after the fledgling and followed it closely on its first aerial journey, in the manner of parent birds of many kinds. For an hour, the young quetzal rested quietly on the branch where it had first alighted; and here the father brought it food. While perching near it, he called many times in a clear but subdued voice, no louder than that of the Jalapa trogon. Meanwhile, the other fledgling, which I had left inside, had climbed up to stand in the doorway of the nest, looking forth. At 11 o'clock, I left them in these positions.

When I returned at a quarter to 2 in the afternoon, I found that the second fledgling had departed and was resting in the *poró* tree in front, where it repeated over and over a beautiful, low, soft whistle. The other, which had flown first, had moved farther down the slope and perched high up in a tree at the edge of the woods. Here the father brought it food and rested close by it when not away foraging. Although this fledgling was given as much as it could eat, the other called and called in vain for attention. Yet its soft whistles carried faintly to the edge of the woods where its father perched. I watched all afternoon; it lingered in the *poró* tree, and the parent did not come near it.

At 5 o'clock, despairing of attracting attention where it had so long perched, the second fledgling suddenly took wing and flew down the slope in the direction where it had last seen or heard its parent. It came to rest in a small tree and continued to call tirelessly. It now began to vary its whistles, uttering some which were longer and slightly sharper than I had previously heard and others that sounded very pleading and mournful. Still no food was brought to appease its hunger.

At a quarter past 5, the neglected fledgling continued down the slope to the edge of the woods, where it came to rest upon a branch of a *cecropia* tree covered over with a dense tapestry of climbing bamboo.

But the other fledgling, accompanied by the father, had long before gone farther into the woods and neither was now in view. The abandoned young quetzal continued ceaselessly to call, until at half past five the male brought the big green fruit of an *ira*, which quieted its cries of hunger. For the next half hour, the parent, doubtless tired by a long day devoted to hunting food for his children, rested quietly on a neighboring branch, without bringing any additional nourishment for the fledgling. At 6 o'clock he flew into the woods and left the youngster alone on the cecropia branch, where it still perched quietly in the gathering dusk and the light rain that was now falling. Here it passed its first night in the open. From the time of my arrival at a quarter to 2, it had received no food, except the single fruit brought to it nearly 4 hours later. I doubt whether its father had given it anything else since the first fledgling left the nest at 10 o'clock in the morning, for, exactly as had happened with a brood of Mexican trogons that I had watched fly from the nest 5 years earlier, he was almost exclusively occupied with the first to take wing.

At dawn, I found the second fledgling on the cecropia bough where it had passed the night. The male arrived with food and led it deeper into the woods. Thus ended my long association with the quetzals.

Going to examine the deserted nest cavity, I found that during the last 9 or 10 days of occupancy, when the parents no longer cleaned it out, waste matter had accumulated to the depth of $3\frac{1}{2}$ inches. The chief components of this debris were the seeds of the lauraceous fruit which the parents brought in such great numbers. These were ellipsoidal, measuring $1\frac{3}{8}$ by $\frac{3}{4}$ inches. Mixed with them were the regurgitated shards of beetles and other hard parts of insects, a few snail shells, a few smaller seeds, and much excrement.

The fledgling quetzals which forsook the nest at the age of 23 days probably left prematurely as a result of having been removed for photography and examination. The lowness of the nest, with convenient trees in front, may also have encouraged their relatively early departure. At my first nest, which was high and inaccessible, the parents were first seen to carry in food on April 21. On May 14, I saw for the first time a nestling appear in the doorway. Two days later, both nestlings were glimpsed in the entrance at once. They departed between the 19th and 20th, when at least 29 days of age. At the higher first nest of the pair whose second brood departed at the age of 23 days, food was carried in as early as April 19, while the last nestling departed on May 20, indicating a nestling period of 31 days. Other available nestling periods of trogons are: Mexican trogons, 15 to 16 days; black-headed trogons, 16 or 17 days; and Baird's trogons, 25 days.

INCIDENTAL OBSERVATIONS

Each of the three pairs of quetzals to which I devoted most attention reared, or attempted to rear, a second brood. Incubation of the first set of eggs began in early April and the nestlings departed about May 20. At least two of these pairs, and probably all three, were successful with their early broods. In June, all three were incubating once more. The two whose 60-foot-high holes were still available, laid their second sets of eggs in the same cavity as the first. I saw one of these pairs cleaning out the old nest, but how thoroughly they performed this task must be left to the imagination. The pair whose 30-foot-high nest we had the inspiration to pull over, after the departure of the fledglings, laid again in a lower hole 50 yards distant from the first, where at last I was able to see the eggs and follow the development of the nestlings whose history we have recorded.

While he incubated the eggs and attended the nestlings, the male quetzal's ornamental plumes suffered severely from constant flexing and from friction against the rough edges of the nest's single entrance. The wear and tear began to tell even before the nestlings of the first brood were old enough to get along without brooding. As early as April 30, I found my second male sitting in his nest with only the short length of a single plume projecting from the doorway to show that he was within. Most of the males, I believe, suffered similar losses by the time the first brood was awing. The point where the plumes broke off was often a little beyond the tip of the tail proper. But at least one male proudly displayed both his banners before his doorway while he incubated the second set of eggs. Possibly he was a new mate of the female who attempted to rear a first brood in the same hole.

On all my visits to their nest, the parent quetzals had never darted at me nor made any display to lure me from its vicinity. They merely perched close by to watch, nervously twitching their tails or at most darting excitedly from branch to branch. In this they agreed with all other trogons I have watched at the nest.

In no other region have I found the birds of nearly all kinds so fearless of man as in the forests of the more remote parts of the Costa Rican highlands. In this respect they differed greatly from those I studied in the Guatemalan highlands, where the human population is relatively dense. The quetzals were by no means the most confiding of the birds; yet I never ceased to marvel that such large, brilliant wild creatures should be at all times so bold in the presence of man. In sharp contrast to the behavior of some other birds I have watched, the quetzals' disregard of the human presence became most pronounced while they attended their nestlings. With the exception of a pair of Baird's trogons that nested last year in the forest near my

house, I have found all the smaller members of the family far more wary. The quetzals would as a rule go about feeding their nestlings while I stood conspicuously nearby. Both of the males that I knew best were at first less trustful than their mates, but they grew more confiding in my presence as we became better acquainted. The nest of one pair was in the same trunk as that of a pair of house wrens (*Troglodytes musculus*). The tiny, dull brown wrens were far more wary than the great, glittering quetzals!

When I took leave of the quetzals in August, after more than a year amid their beautiful but uncomfortably wet forests, they had become as silent as when I first found them and they wore only the tattered remnants of their full plumage.

SUMMARY

The quetzal (*Pharomachrus mocinno*), one of the most magnificent birds of the Western Hemisphere, has a long history of human association. Its plumes were used for personal adornment by Indian royalty and nobility in pre-Columbian times. The bird is the emblem of the Republic of Guatemala, whose monetary unit has been named for it. A number of legends have gathered about the quetzal.

The quetzal is an inhabitant of the lofty, humid forests of the Subtropical Zone, ranging from 4,000 to 9,000 or 10,000 feet above sea level in Costa Rica, somewhat lower in Guatemala. Where these forests are destroyed, the bird disappears. It is at present protected by law in Guatemala, but owes its survival largely to the inaccessibility of its habitat. While making this study, the writer dwelt for a year in a part of the Costa Rican cloud forests where quetzals were abundant.

The appearance of the quetzal is described from notes taken while observing the living bird. The female is exceptional among trogons in the large amount of green in her plumage.

The bird eats many small fruits, which it plucks on the wing, in the manner of other trogons.

Its vocabulary is varied: a loud note, given in flight, was heard throughout the year; additional notes were heard during the mating and nesting periods.

In the breeding season, the male often rises above the treetops in a flight display, calling loudly as he goes. No other trogon, nor rain-forest bird of any kind, is known to make similar flights.

The quetzal is found in pairs in the breeding season, and usually singly at other times. Flocks have been reported, but no trogon is known to be truly gregarious.

In the Costa Rican highlands, the nesting season extends from early April to July or August. Two broods are reared, where possible in the same nest.

The quetzal nests in a hole resembling that of a big woodpecker, with a single round doorway at the top. Old woodpecker holes may be enlarged to serve its purposes, but at other times it appears to excavate a new cavity in decaying wood, male and female working alternately, in the manner of other trogons. No lining is taken into the cavity. The same hole appears to be used in successive years.

The eggs are light blue; there are apparently two in a normal set.

Male and female share the duty of incubation. Each takes two turns on the eggs in the course of 24 hours, the female during the night and the middle of the day, the male in the early morning and late afternoon. There is considerable variation in the actual times of nest relief, even from day to day with the same pair; but this general scheme seemed to be consistently followed by the two pairs studied in detail. Each sex may interrupt its period in charge of the eggs by one or more brief recesses. The male sits about 6 or 7 hours each day. Quetzals incubate far less patiently than many smaller trogons.

Upon leaving the eggs at the end of a session, the male sometimes rises directly into the air in a flight display.

The period of incubation is 17 or 18 days.

The nestlings are hatched with perfectly naked, pink skin and tightly closed eyes. The heels are studded with papillate protuberances. The pinfeathers begin to push through the skin when they are about 2 days old. The contour feathers begin to escape their sheaths at about the seventh day after hatching; and by the fourteenth day the young birds are well clothed on the body but not on the head. The eyelids begin to separate at about the fifth day, and by the eighth day the eyes can be opened.

During the first 10 days, the nestlings were fed almost exclusively on insects and other small invertebrates. From this age onward, fruits became increasingly important in the diet, especially the large, hard, green fruits of the laurel family (Lauraceae). The diet of the young quetzals was amazingly varied, including beetles and other insects of many kinds, larvae, small frogs, small lizards, land snails, and hard fruits. Feedings were infrequent; but the portions were substantial.

Empty egg shells were promptly removed by the parents, who kept the nest clean during the first 10 days or so of the nestlings' life, in this respect differing from other trogons. After that, waste matter began to accumulate. The big, regurgitated seeds formed the chief bulk of this debris, which raised the level of the floor $3\frac{1}{2}$ inches, before the departure of the fledglings.

One of the females became inattentive while her nestlings of the second brood were growing up. After the seventeenth day she was not seen at the nest. During the last 6 days in the nest, and so far as

seen after the departure of the fledglings, the male was the sole attendant.

The nestlings, dull blackish on the upper parts when first clothed with feathers, became increasingly green after they were 2 weeks old. This was accomplished by overlaying the down feathers by green-tipped contour feathers whose development had at first lagged behind that of others in the same tract. The expansion of the feathers of highland trogons and motmots begins earlier than with their lowland relatives but may be carried out more gradually. This appears to be an adaptation to the cooler climate of the highlands.

Two nestlings, which had been removed for photography and examination, flew from their low nest at the age of 23 days. In two high, inaccessible nests, the nestlings remained for about a month.

The first fledgling to leave the nest received at first the whole attention of its father, while during 4 hours or more the second called in vain for food. At the end of the day, the parent returned to feed the second fledgling.



A CLEARING IN THE FOREST NEAR VARA BLANCA, 5,500 FEET, COSTA RICA

A pair of quetzals nested at the edge of the forest at the lower end of this clearing, July 1938.



BORDER OF THE SUBTROPICAL FOREST, NEAR THE HEADQUARTERS OF THE RIO SARAPIquí, 5,600 FEET, COSTA RICA, JULY, 1938



FEMALE QUETZAL AT THE NEST, ABOUT TO DELIVER A GOLDEN BEETLE TO THE NESTLINGS, JULY 20 1938.

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NESTLING QUETZAL, 21 DAYS OLD, AUGUST 1, 1938.

THE SUN AND THE HARVEST OF THE SEA¹

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[With 10 plates]

None of the preceding Arthur lectures, of which this is the fourteenth, have particularly concerned themselves with the sun's relation to life in the oceans and the food that man harvests from that abundant life. Those who attended the previous lectures or read them as published perhaps gleaned a few memorable facts regarding the sun and its importance in the daily life of man and to the world about him, but others may not yet have had these facts presented to them. Therefore, I beg to recall at this point a few facts regarding the relative size of the sun and the earth, the land area of the earth as compared to the sea, and the sun's output of energy upon which all living things ultimately depend.

RELATIVE SIZE OF SUN, EARTH, AND SEA

Fabre, in his delightful series of little essays entitled "This Earth of Ours," tells us that the sun, as compared to the earth, is enormously large—over a million times larger than the earth; that if the sun's center coincided with that of the earth, it would reach about as far beyond the moon as the moon is distant from the earth. The moon is some 240,000 miles removed from the earth; its diameter is 2,160 miles. The sun's diameter is roughly 860,000 miles; that of the earth 8,000 miles. Between the earth and the sun some 93 million miles of space intervene.

From H. A. Marmer's informative treatise on "The Sea" we learn that the area of the earth totals approximately 197 million square miles, of which 139½ million square miles (71 percent) are sea and 57½ million square miles (29 percent) are land. The greatest ocean depth is 35,400 feet below the level of the sea; the highest mountain, Mount Everest, rises 29,000 feet above it. Though the average depth of the sea is only 2.36 miles (12,450 feet), the total volume of water in the oceans is 11 times that of all land above the level of the sea.

¹ Fourteenth Arthur lecture, given under the auspices of the Smithsonian Institution March 5, 1946.

If all land above and below the ocean waters were leveled off around the globe, sea water would cover the land to a depth of $1\frac{1}{2}$ miles.

THE SUN'S ENERGY

Our weather, as Dr. Abbot has shown us in earlier lectures in this series, depends upon solar activity. Without the sun there would be no winds, no evaporation, no clouds, no precipitation, no fog or rain, sleet or snow, no ocean currents, no springs or streams to return water to the sea to complete the cycle which fertilizes and irrigates the land, as well as the sea.

From the sun the earth receives the energy which warms it and makes it a habitable place for living things, and which enables plants to grow, to synthesize, to utilize, and to store that self-same energy in the form of carbohydrates. This process, peculiar to plants alone, by which they can manufacture starches, sugars, and other substances from carbon dioxide and water under the influence of sunlight, is called photosynthesis.

It has been estimated that the energy that the earth receives from the sun totals 240 trillion horsepower. For all its magnitude, this figure represents just about two-billionths of the sun's total output of energy, which, boiled down to simple figures, on a good sunny day, amounts to 1 horsepower per square yard of the earth's surface.

A very considerable part of the energy received from the sun goes into the maintenance of the water cycle between the ocean, atmosphere, and land. In the conclusion of his study of this cycle, Dr. George F. McEwen, of the Scripps Institution, remarked,

* * * The annual precipitation over all the oceans is 80,000 cubic miles, or 244 units, if the volume of the ocean is 1,000,000, and the annual evaporation from the ocean surface is 89,000 cubic miles, or 272 units. Thus a run-off from the land to the oceans of 9,000 cubic miles, or 28 units, is required to balance precipitation and evaporation, and the whole process involves an expenditure of 500,000 horsepower from the sun for every square mile of the earth's surface. * * *

Five hundred thousand horsepower is perhaps the maximum peak load that our local power plant (Potomac Electric Power Co.) could possibly deliver; its actual steady delivery of energy is nearer 380,000 horsepower. Thus, in order to keep the earth's water cycle in motion, a power plant at least as large as the huge Pepco installation at Benning, D. C., operating continuously at peak load—which is impossible—is needed, one for each square mile of the earth's surface. As has been already pointed out, there are 197 million square miles of surface to the earth. It is inconceivable that man could supply the fuel for such a power network. Today you might quickly say atomic energy, not realizing the time, money, material, and plant size that is now needed for the production of a very limited supply of man-made atom bombs.

The sun's energy, as you may have heard, is atomic, resulting from the transmutation of hydrogen into helium. We know the sun gives up energy as hydrogen gas becomes helium. The mechanism is perhaps unknown to us. The sun spots are magnetic fields of tremendous size and power. Could they be solar cyclotrons splitting the hydrogen atom?

HYDROPONICS, TERRESTRIAL AND OCEANIC

The ocean has been described as the world's largest septic tank, but this concept is descriptive of a very small part of the marvelous organic mechanism that is the sea. The comparison is based upon the activity of bacteria in the septic tank, as well as in the sea, in bringing about the reconversion of complex plant, animal, and mineral substances for reuse by living organisms. More apt, and permitting better visualization of the processes involved, however, is a comparison of the oceans with a sizable hydroponics installation.

Such an installation was set up on Ascension Island by the Air Transport Command of the Army during the war, when both the Army and the Navy, by force of circumstances, became hydroponics-conscious. On that largely soilless island so strategically placed in mid-south Atlantic on the principal military air route from the New World to the Old, fresh vegetables were urgently needed in quantity for great numbers of men, men in transit and at work keeping other men, planes, and supplies flowing in an unending stream to the African and mid-European theaters of war.

Even if garden produce or the foodstuffs to take its place could have been obtained elsewhere, neither the ships nor planes to move it were to be had. Ships and planes were too limited in number to be diverted from the urgent war missions in other directions. Hydroponics was the only possible solution of a pressing problem.

To undertake hydroponics, the soilless culture of plants, or nutrienture, as the more recent publications on the subject have it, on any comprehensive scale, a series of tanks or waterproofed troughs must be provided to hold the nutrient solution in which the plants are grown. Gravity is the cheapest means of circulating the solution through the tanks or troughs if the installation is such as to permit it, as on Ascension Island. In any case, pumps must be used to areate as well as to return the nutrient solution to its original container for redistribution, whether replenished or not. In lieu of the soil in which the plants naturally grow, support of some kind has to be provided. The smaller installations have metal or wooden racks in which the plants are embedded in excelsior or sphagnum moss or both, so that the roots will hang down into the solution in the tank below. In the larger installations the supporting medium may be

sand, cinders, gravel, or crushed rock. On Ascension volcanic ash or pumice was used.

The nutrient solutions of our land or shore installations are made up of salts of the principal plant foods, calcium, magnesium, phosphorus, sulfur, and nitrogen, with the addition of indispensable "micronutrient supplements," chiefly iron, copper, manganese, molybdenum, and zinc. With one notable exception, the composition of this nutrient solution is quite similar to that of sea water. That exception is sodium chloride, which forms approximately 78 percent of the total dissolved solids in sea water. To marine plants in the usual concentrations this salt is harmless, to land and fresh-water plants it is quickly lethal. There is no problem regarding micronutrient supplements in sea water, for all the supplements that are ever supplied land plants, along with many more, including at least traces of a majority of the known elements, are present in sea water.

In the seven seas we have the world's greatest hydroponics set-up, with a limitless supply of nutrient solution immediately at hand. In the oceans, as in the hydroponics tanks, no plant growth is possible without the energy given up by the sun. Besides the nutrient materials in solution, plants must have unlimited supplies of carbon dioxide and water for their photosynthetic processes. The land plants derive their carbon dioxide from the atmosphere, their water from the nutrient solution. In the sea carbon dioxide, either as the dissolved gas or in the form of readily hydrolyzed bicarbonates, is so abundant as never to be a limiting factor to plant growth. When the nutrient solutions in the hydroponics tanks become exhausted the needed chemicals are added or fresh solutions made up and circulated through the tanks. In the sea comparable enrichment is brought about by the leaching and erosion of the constituents from the land,² as well as by the end products of the bacterial decomposition of past generations of marine plants and animals and the breaking down of complex inorganic substances.

All the plant foods thus released, replenishing the nutrient seawater solution, are redistributed and circulated by currents powered in large measure by the heat of the sun and in part by the earth's rotation, which likewise is dependent upon the sun's attraction. The earth's rotation also brings about pronounced upwellings along the west coasts of continents, notably the west coast of the Americas and West Africa. These upwellings, along with convection currents, due to differences in temperature and salinity of various bodies of water, bring up other still untouched reserves of plant foods and dissolved gases for the use of the plants in the photic zone. Thus the nutrient

² Coker ventures the estimate that 3 billion metric tons of material from the land is annually being dumped into the sea.

solution is renewed and kept in constant circulation and is also aerated. Important adjuncts to the mixing apparatus of the oceans are the drifts and tides, the waves and breakers, and the winds and storms.

THE MEADOWS OF THE SEA*

The plants which form the greater bulk of plant life in the sea are microscopic, swimming or floating freely but more or less passively at or relatively near the surface. That this planktonic plant life is so very tiny is Nature's way of meeting the problem of deriving nutriment from a very dilute solution. The salt content of water is generally expressed in parts per thousand, per mille, instead of percent. It is a well-known physical fact that the smaller the body, the greater the ratio of surface to volume. The greater the surface for a given body, the greater its power of absorption of the nutriment from solution as well as energy from the sun. Best known of these plant forms are the diatoms and the dinoflagellates or peridinians. They have been most intensively studied not only because they are so numerous, but also because they can be so conveniently screened from the sea with the fine-meshed silken tow nets generally used for sampling plankton.

Less well known because of their very much smaller size are other plant forms which readily pass through the meshes of the tow nets, even though the meshes run as small as sixty-four hundredths of a millimeter. We speak here of the coccolithophorids, the yellow algae, as distinguished from the yellow-green diatoms, which under ordinary circumstances seem only to be caught by accident in our silk nets. They are obtained for study by centrifuging sea water, or by running it through filter paper. By some investigators the role played by the coccolithophorids in the economy of the seas is considered at least as important as their larger relatives, the diatoms and peridinians, along with a widely distributed true green algalike plant, *Halosphaera viridis*. In the Antarctic region this plant is one of the dominant forms of planktonic plant life, standing next in importance to the diatoms.

As the plants in the hydroponics tank need support of some kind, so also must the marine plants be supported in their nutrient medium if they are to remain within the so-called photic zone. This zone comprises that part of the upper levels of the sea to which the sun's light and radiant energy penetrates in sufficient strength to permit photosyn-

* Not mentioned are the algae of the littoral zone, including the giant kelps and floating sargassum, and the higher forms of marine plants such as the eel grass of northern waters and the turtle grass of southern waters. All play important roles in the economy of the sea. The story of their several roles is as interesting as the one involving the planktonic forms of plant life.

thesis to take place. Though the blue-violet rays of sunlight may be detected at depths as great as 500 fathoms, and green light somewhat lower down, the red rays, the most effective photosynthetically, are probably all absorbed in the upper 250 fathoms. At just what depths photosynthetic activity may still be possible for marine plants is yet to be definitely determined, but surely for the diatoms it must be very limited to at most 50 fathoms, even under the most favorable circumstances.

When the phytoplankton sinks below the level where photosynthetic activity is no longer possible, it soon perishes. Remaining afloat within the higher levels of the sea, therefore, becomes a matter of life or death to all planktonic plant life.

Living matter is heavier than sea water. Its higher specific gravity must be compensated in some fashion if sinking is to be retarded. We find many adaptations among marine plants designed to achieve this end, the storage or retention within the body of lighter materials, such as oil droplets, various fatty substances, and even water of a lower salinity than sea water, and the inclusion of air or gas in vacuoles. Hard parts are usually drastically reduced. By the development of projecting horns or branches or bristlelike structures, by taking on a bladderlike or floatlike form, or by the forming of aggregations, ribbons, or chains of individuals, surface area is increased and with it the ability to remain afloat. Here again small size is of great advantage. Just as reduction in body size increases the ratio of surface to volume and facilitates absorption, so a high ratio of surface to volume retards sinking, especially in a solution as heavy and viscous as sea water. Some diatoms take on a slender rodlike or hairlike form which also facilitates floating in a horizontal position. Vertically, sinking would be thereby accelerated, except for a further adaptation to overcome this tendency. These slender forms are either a little curved, or have sloping or oblique ends, so that in pressing against the water in sinking, the diatoms are rapidly turned back to a horizontal position. The horns with which some dinoflagellates are provided are also bent in order to keep these organisms broadside on, retarding sinking. The dinoflagellates, as the name implies, are provided with a pair of flagella with which the plant can propel itself after a fashion. Most coccolithophorids are also flagellated, motile forms.

The various floating forms of plant life are found in incredible numbers over wide expanses of all oceans and form the so-called meadows of the sea. Not in kind, but in the manner of their culture, they correspond, for the purposes of our discussion, to the plants grown hydroponically.

From time to time investigators have made estimates or contributed remarks regarding the abundance of the phytoplankton in areas with

which they have been concerned, chiefly in the North Temperate Zone, where some of the world's greatest fisheries are found. On the basis of a very rich diatom haul in Kiel Bay, the marine biologist Brandt calculated that the estimated $11\frac{1}{2}$ cubic meters of water that passed through the silk net on that occasion contained about 9,000 millions of diatoms, or about 6,000 per cubic centimeter. Hensen, working in the west Baltic Sea, estimated the average number of diatoms in that area to be about 457 millions per cubic meter, or 457 per cubic centimeter. Apstein found the commonest species of dinoflagellates to be less numerous than diatoms, but that, even so, they occurred at the rate of from 1 to 10 million for each square meter of the surface. In the Skager-Rak, in Norway, Gran estimated on the basis of another rich diatom haul that there was at the time an average of 228 million diatoms per square meter of surface in that body of water. An American, Peck, as the result of a quantitative study made at Woods Hole and in Buzzards Bay, claimed a total of some 420 million diatoms per cubic meter of sea water for some of his largest catches. Herdman and his associates, working in the Irish Sea, have made many interesting contributions to our knowledge of marine biology. They tell of several notable diatom catches made with small nets in brief tows, netting on one occasion 150 millions of *Chaetoceras* and on another 180 millions of *Rhizosolenia*. Moore, from a study of the carbon dioxide consumption of the phytoplankton of a 16-square-mile area of the Irish Sea, estimated that this area produced on the average 2 tons of dry organic matter, equal to 10 tons of moist vegetation per acre, a yield that does not compare unfavorably with the yield of cultivated land. Bigelow, in his report on the plankton of the Gulf of Maine, figuratively throws up his hands at the futility of calculating the abundance of phytoplankton, saying that, "When such numbers⁴ as I have listed as examples are expanded from the trifling bulk of a cubic meter of water to cover the 36,000-square-mile area of the Gulf of Maine north of its offshore banks and to a stratum at least 20 meters thick, they become too vast for the human mind to envisage."

In general, the chemical composition of the crops of the sea is not so very unlike average meadow hay. Diatoms, the most studied constituents of the phytoplankton, show about the same proteid and fat content, somewhat lower carbohydrate content, but considerably more ash due to their siliceous shells; the peridinians very closely approximate better than average meadow hay in proteid and carbohydrate content, though falling a little below in fat and ash.⁵

⁴ These numbers are based on the number of cubic centimeters of plankton taken per standard half-hour haul of a No. 18, 0.079-millimeter-mesh silk net. These catches varied from very meager ones to some containing nearly 600 cubic centimeters of plankton.

⁵ After Johnstone.

Crop	Proteid	Fat	Carbohydrate	Ash
	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
Ordinary meadow hay.....	8.7	1.7	83.6	5.8
Good meadow hay.....	13.6	3.2	75.0	8.2
Average.....	11.15	2.45	79.30	7.00
Diatoms.....	10.0	2.8	22.0	65.0
Peridinians.....	13.0	1.3	80.5	5.2
Average.....	11.50	2.05	51.25	35.10

MARINE HERBIVORES AND CARNIVORES

Any attempt by man to harvest directly the microscopic plant life forming the meadows of the sea would be as impracticable as to grow forage hydroponically for meat production. Fortunately, this will never become necessary, as nature has provided herbivorous animals specifically adapted to graze those vast oceanic fields and to convert their forage crop into animal food acceptable to the higher and more carnivorous forms of marine life, as well as to man himself.

The marine herbivores, as well as the marine carnivores that prey on them, are well adapted to moving about in their watery environment. All are motile to a greater or less degree; the protozoa or single-celled animals are flagellated or ciliated, as are the larvae of most marine invertebrates, or provided with pseudopodia; some, like the jellyfish, squids, and octopi, are after a fashion jet-propelled; most crustacea have oar- or paddle-feet for locomotion when they are not strictly sedentary or ambulatory forms. The marine vertebrates, as a rule, have powerful tails to drive them forward, assisted by fins and flippers used also for balancing. Most, if not all, of the various adaptations for facilitating flotation in plants are repeated in one form or another in the animal life of the sea: expansion of the body; the development of bristles, setae, and horns; the storage of oil droplets and fatty material; and inclusion of gas or air in the bladders of certain fishes.

The number of grazers on the meadows of the sea is also a measure of the productivity of those fields. The principal grazers are the Crustacea, foremost among which in numbers and in consumption of phytoplankton are the small relatives of the shrimps known as the copepods. Various estimates have been made of the abundance of copepods. The North Sea is believed to support from a quarter of a million to a million per square meter of surface. For the West Baltic Hensen estimated a total of something like 80,000 per cubic meter, or 80 to 100 billion to each square mile of surface. Gulf of Maine averages reported by Bigelow ran from 6,000 to 500,000 per square meter of surface. His record catch of copepods was obtained in the course of a 15-minute vertical haul, July 22, 1916, from 40-0 fathoms. The net on this occasion yielded about 6 quarts of large calanoid copepods,

roughly 2,500,000 individuals, chiefly *Calanus finmarchicus*, the dominant copepod in the Gulf of Maine. The abundance of this species makes it the most important North Atlantic consumer of marine plants on the one hand and the most valuable food for the larger carnivorous marine animals, both invertebrate and vertebrate, on the other. According to Farran, in the path of the Labrador current along the coast of North America *Calanus finmarchicus* forms in the summer months a rich belt which is at least 500 miles wide off Newfoundland.

An evaluation of what copepods mean in terms of diatoms and peridinians has been made by Johnstone. He found that while it took from 300,000 to 500,000 copepods to make 1 gram of dry copepod substance,* an equivalent mass of dry phytoplankton material required 675 millions of specimens of the diatom *Chaetoceros* or 42 to 65 millions of peridinians. On this basis 1 copepod contains about as much substance as 135 peridinians or 1,687 diatoms. The dry substance of 1 peridinian equals that of 12 diatoms.

Coming back now to the Gulf of Maine, where Redfield restudied the distribution of the calanoid community in 1933 and 1934, we learn that the average haul for all sectors of the Gulf and for all cruises consisted of about 40 cubic centimeters of "dry"† plankton. This, if the area of the Gulf be taken at 36,000 square miles, according to Redfield's figures, would indicate a total population of primarily crustacean grazers aggregating some 4 million tons. Copepods predominated among the crustacean grazers making up this immense mass of animal matter nurtured in that body of water. Yet the euphausiid shrimps must have formed no inconsiderable part of that mass. Though figures as detailed as those available for the copepod grazers are not at hand for the euphausiids, it is known that in various places they occur in almost equally great numbers. Bigelow speaks of several half-hour surface and vertical hauls from 60 to 100 meters which returned 500 cubic centimeters of zooplankton, "chiefly euphausiids." S. I. Smith and Verrill have told of the swarms of euphausiids in the Eastport region "filling the water for miles," and of the occasion when they were so abundant among the wharves at Eastport that they could be dipped up by the quart. From a study of the food habits of certain fishes and whales, euphausiids are seen to be as important as copepods in converting the ocean's pasturage into food for higher animals, carnivorous and omnivorous.

Most animals feeding directly on plant or animal plankton are equipped with filters, or strainers, which enable them to strain these small organisms from the water. The filtering apparatus in crustaceans, which include the euphausiids and copepods, is made up of

* Dry weight in this instance is based upon a completely desiccated sample.

† The plankton, after removal from the tow net, was collected on filter paper and suction applied to the funnel until the fluid in which the catch was preserved ceased to flow.

appendages richly supplied with bristles or setae; in the fishes the gill rakers and in the whalebone whales the fringes of the plates of baleen serve the same purpose. Other filter feeders are found among the shellfish, such as the oysters, mussels, and clams, and among the lower chordates, of which the pelagic forms, such as the salps and appendicularians, have filters so fine and delicate that they strain out the coccolithophorids for whose successful capture man must centrifuge the water or employ filter paper.

The structure of the apparatus determines the type of food ingested by the filter feeders. The great majority of the copepods, as well as the euphausiids, have their filters adapted to the capture of phytoplankton. In the plankton-feeding fish there is a nice adjustment between the armature of the gill arches constituting the water-straining mechanism and their food. First and foremost among the plankton-feeding fish are the clupeoids, or the herrings, and their relatives, the menhaden, sardines, alewives, and shad. Bigelow has remarked that the menhaden "has no rival among the fishes of the gulf [of Maine] in its utilization of * * * pelagic vegetable pasture; nor is any other local species possessed of a filtering apparatus comparable to that of the menhaden for fineness and efficiency, though in European waters its relative, the sardine, feeds equally on microscopic plankton as well as copepods." As fine-straining as the menhaden's sieve may be, it is unable to retain coccolithophorids. The herring's gill rakers, though they may retain masses of the larger floating algae, seem particularly adapted to the capture of copepods, their chief source of food.

The mackerel, with somewhat widely spaced spines on the gill rakers of the first gill arch, may at times pick up more or less phytoplankton if composed of fairly large species. Like the herring, the mackerel has a sieve more especially suited for the capture of copepods.

Differentiation in filter mechanisms determining feeding habits extends also to the various species of whales. The finback and humpback whales, with rather coarse and comblike fringes, feeds largely on fish, herring, and sardine, and on the larger zooplankton, particularly euphausiids. The pollock whale, with "unusually fine and curly" fringes, almost wholly bristles, and the right whale, with "silk-fine" fringes, strain out plankton animals as small as copepods, which sometimes are exclusively their food, though at times they feed on euphausiids either along with the copepods or when the latter are unavailable.

In the whalebone whales, the food-carrying water is taken into the mouth and strained as it is forced outward through the fringes of the baleen plates by the tongue as the mouth is closed. In the

fishes, on the other hand, the food is strained as the water passes backward through the mouth between the gill rakers and out of the gill openings. The amount of food found in the stomachs of various filter feeders examined by investigators is prodigious: a small copepod was found to contain 120,000 diatoms, a herring, 60,000 copepods, a Pacific humpback whale, from 1,500 to 3,000 pounds of sardines, besides a miscellaneous lot of smelt, anchovies, hake, shrimp, and squids; and a blue or sulphur-bottom whale, which has coarse-fringed baleen plates like the humpback, but takes no fish, over 300 gallons of euphausiids. For a blue whale to have as much as a ton of crustacean remains in its stomach is no novelty in some of the larger specimens taken in the Antarctic.

Filter feeders are not the only marine carnivores. Indeed, they are the chief sustenance of many other carnivores. The herring is an important source of food to many inhabitants of the sea. It is preyed upon by innumerable fish (rockfish, cod, haddock, pollock, hake, albacore, and dogfish), squid, whales, seals, and porpoises. The eggs and young of most fish, including the herring, constitute a source of food for many predaceous creatures, including the glass or arrow worms, the pelagic worm, *Tomopteris*, and the pelagic amphipod, *Euthemisto*, jellyfish, and comb-jellies. The glass worms, in turn, are preyed upon by whales, herring, mackerel, salmon, and medusae. The adult herring retaliates for the injury that *Tomopteris* does to its young by making this worm part of its dietary. *Euthemisto* furnishes food for more animals than has been hitherto realized. Captain Bartlett, who saved the stomachs of many animals that he collected in the Arctic regions, found that *Euthemisto* was eaten in quantity by the sulphur-bottom whales, ringed and harp seals, and codfish. Mackerel have long been known to relish this amphipod. Though the common mackerel is largely a filter feeder, it frequently eats other smaller fish—herring, menhaden, anchovies, silversides, and the sand lance. The latter at times has been found also in herring stomachs. Feeding on the mackerel in turn are sharks, which are said to be their worst enemies, cod, bluefish, porpoises, whales, and squid. The larger relatives of the mackerel include the tunas and the albacores, both voracious carnivores. The salmon at sea are wholly carnivorous. Even among the copepods there are some carnivorous species which prey on their inoffensive filter-feeding relatives.

Though some of the more important groups of marine herbivores have been briefly discussed, only a few of the many marine carnivores have been referred to. It is believed, however, that this discussion will give some idea of the food relations of the animals and plants of the sea and of the ultimate dependence of the animals, through the intermediation of the plants, upon the energy given off by the sun.

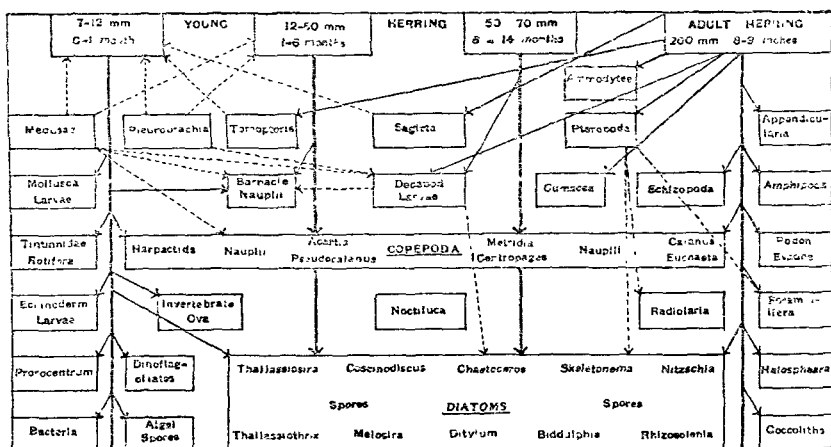


FIGURE 1.—Food relations of the Pacific herring, *Clupea pallasii*. In this diagram the complex relations of the various marine animals and plants entering into the diet of herring are set forth. The arrows point to the food eaten, the solid lines indicating that consumed by herring, the dotted lines that consumed by other animals. It has not been possible to figure all the animals and plants mentioned in this diagram, but most of them will be mentioned, described, or figured in one or more of the works cited in the selected bibliography, page 310. (Courtesy of G. H. Wallis, from the Vancouver Museum Notes.)

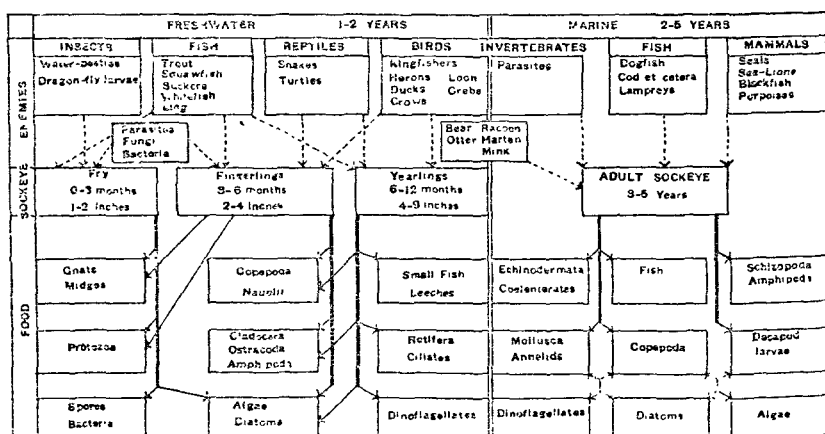


FIGURE 2.—Food relations and enemies of the sockeye salmon, *Oncorhynchus nerka*. In this diagram the complex relations of the marine animals and plants entering into the diet of the salmon, as well as the species of animals preying upon the salmon, are set forth. The arrows point to the food eaten, the solid lines indicating that consumed by salmon, the dotted lines that consumed by other animals. It has not been possible to figure all the animals and plants mentioned in this diagram, but most of them will be mentioned, described, or figured in one or more of the works cited in the selected bibliography, page 310. (Courtesy of G. H. Wallis, from the Vancouver Museum Notes.)

These relationships may be best reviewed in diagrammatic form. To that end, three diagrams outlining them are here reproduced. The first sets forth the food relations of the Pacific herring. It is particularly to be noted that herring at all growth stages, in addition to whatever other food they may consume, including some algae, feed to a very large extent on copepods. These, in turn, derive their sustenance almost wholly from diatoms. Not indicated in the diagram are the animals, including man, which prey upon the herring.

In the second diagram attention is called to the marine phase of the life of the sockeye salmon as an example of the food relations of a fish wholly carnivorous as an adult. Plant food does not directly enter into its dietary. Man is not here shown as an enemy of the salmon.

The third diagram is both a summary and an amplification of all that has been said regarding the relations of the sun's energy to the life in the sea. The input of solar energy is indicated, but not the "take" that constitutes man's harvest of the sea.

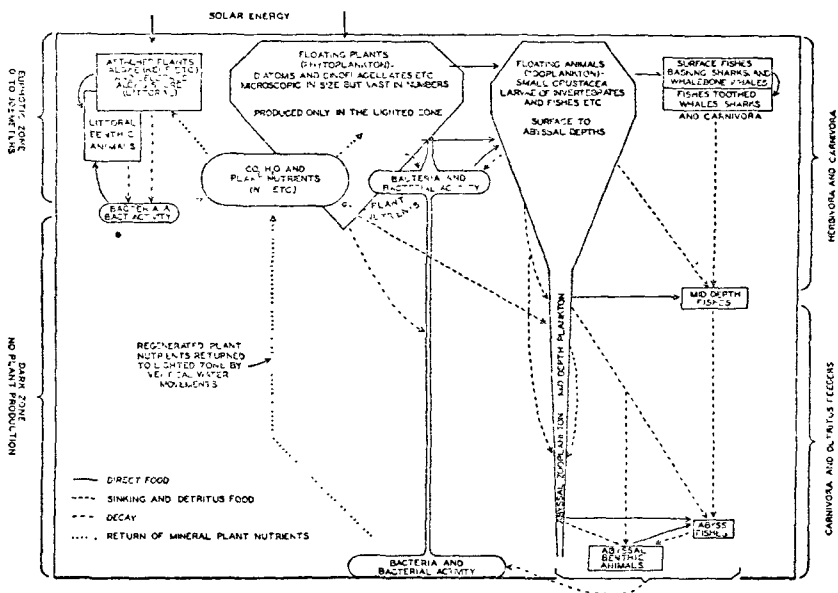


FIGURE 3.—Diagram showing the main features of the interrelations of marine organisms, both plants and animals. The several volumes indicated are not based on computation and should be considered as being only very roughly proportional and presented only as an aid to the visualization of conditions. The volume of plants is indicated as greater than that of animals, whereas actually there are seasons when it is less. (From *The Oceans*, by Sverdrup, et al. Courtesy Prentice-Hall Inc., publishers.) In the diagram is indicated the contribution of solar energy to the economy of the sea, as well as the role played by bacteria as reconverters of organic and inorganic materials.

THE HARVEST OF THE SEA

As space limitations have prevented more than a brief mention of a few of the marine plants, grazers, and carnivores, so they also preclude here all but a few statistics concerning the harvest which man takes from the sea. Accompanying these figures are diagrammatic summaries of the Pacific salmon and the world's herring fish-

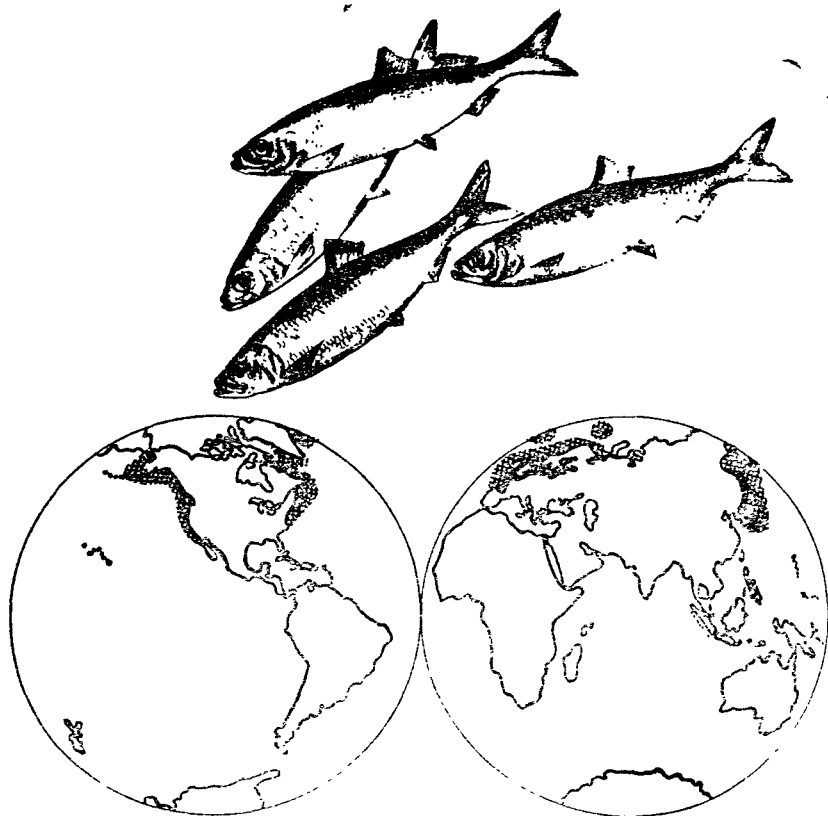


FIGURE 4.—World production of herring.

European production, including Iceland, 3,000 million pounds.

Eastern coast of North America, 225 million pounds.

Western coast of North America, 350 million pounds.

Japanese production, 700 million pounds.

Siberian production, unknown.

(Courtesy Fish and Wildlife Service.)

eries because they pertain to fishes for two species of which food relations diagrams are given above.

As great as these graphically presented harvests are, perhaps the most spectacular is the harvest resulting from the whale fisheries of the world, which in 1938 accounted for about 55,000 whales of all kinds. The principal product of this harvest is whale oil, which had

in the more normal years a market value of between 19 and 20 million dollars annually. This same fishery for each of the 8 years previous produced on the average 30,000 whales per year.

The world participates in the tuna harvest. This, in normal times, amounted to 675 million pounds of fish, of which the United States'

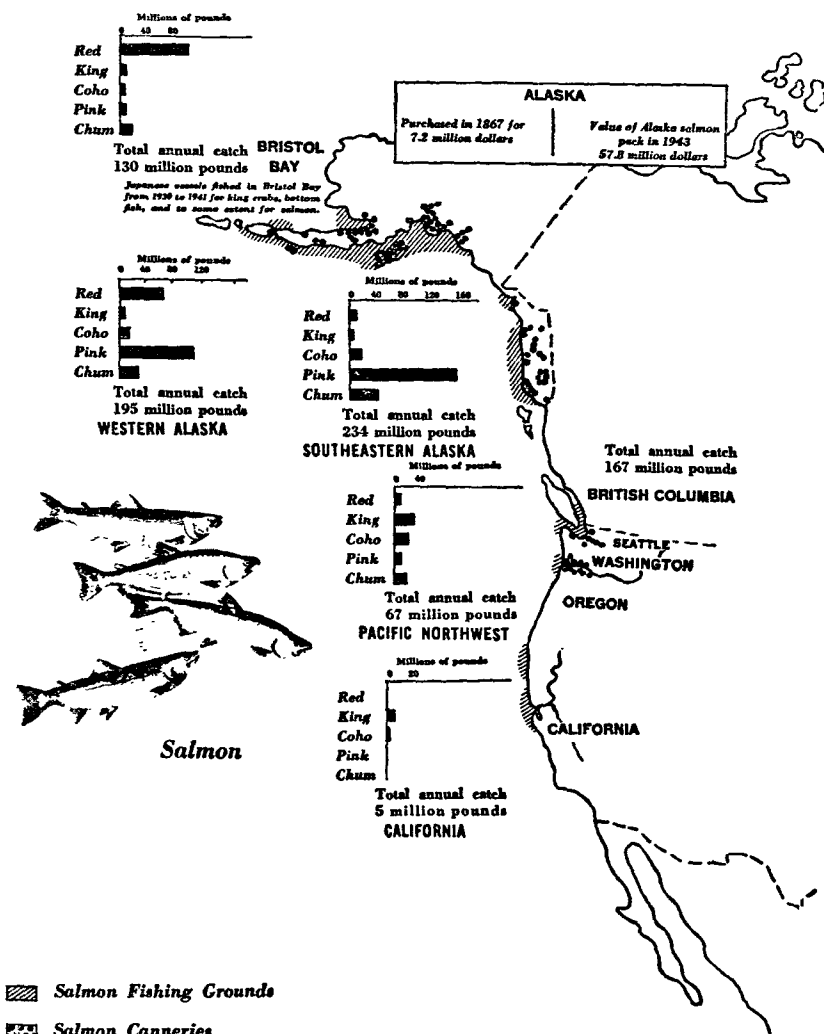


FIGURE 5.—Salmon production and distribution, and location of canneries for the west coast of North America, with value of Alaska salmon pack for 1943. (Courtesy Fish and Wildlife Service.)

share was 23 percent. The salmon represent the United States' most valuable fisheries resource, in 1943 exceeding in value the original purchase price of the Territory of Alaska more than eightfold.

The halibut harvest in Atlantic waters over the years dropped from a previous high of 14 million pounds to its present level of about

1 million, but the loss in that area has been more than compensated by the great increase in the yield of the Pacific halibut banks, which, from relatively small beginnings before the turn of the century, reached a high of 69 million pounds in 1915 with unrestricted fishing. Today the annual harvest is nearer 50 million pounds under regulation which has resulted in a catch per unit of gear 112 percent greater than in 1930.

Among the fisheries of the Western Hemisphere, that of the Pacific sardine or pilchard is outstanding. It is the largest in the hemisphere, averaging today 1,000 million pounds a year. It accounts for nearly 25 percent of all fish caught in the United States.

Of the lowly oyster, the American harvest alone totals 89.8 million pounds of oyster meat, equivalent to 160,360 beef cattle in edible flesh.

The total capitalized value of the United States fishery resources alone is \$5,855,000,000. The total world production of fish is estimated at 13 million tons, or 26 thousand million pounds.

At one time or another surely we all have made the acquaintance of cod-liver oil. We know its source, its high medicinal value, and are aware that it has long been familiarly called bottled sunlight. Whether we believe it or not, modern research in the field of vitamins and irradiation of foods has proved that statement to be literally true. From the sun to the oil extracted from the cod's liver is but one short step.

As the sun sets once again at the harvest's end, it may be a little less difficult to understand the utter dependence of the sea's abundant harvest on the sun than was possible at the beginning of this brief discourse.

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EXPLANATION OF PLATES

PLATE 1

Hydroponics installation on Ascension Island, covering 80,000 square feet of ground, with windbreaks and sunshades. Center photograph shows the type of waterproofed concrete troughs that were built. They were constructed on several levels, to facilitate the gravity flow of nutrient solutions from the higher to the lower levels. From the lower end of the system the solutions were pumped back to the higher level for recirculation, with replenishment of nutrient solutions as required. In full production, lettuce, tomatoes, cucumbers, green peppers, radishes, beans, and other greens were raised in quantity. (Courtesy Army Air Forces and Purdue University.)

PLATE 2

UPPER: Sample of diatom-rich phytoplankton in which a number of species are represented: *Lauderia glacialis*, the large disklike forms; *Thalassiosira*, chains of tiny boxlike diatoms, of which a few isolated specimens present the circular face view; *Chaetoceras*, chains of long-bristled, laterally rectangular cells; *Rhizosolenia*, stout-pointed rodlike forms; and *Thalassiothrix nitschioides*, slender needles. All these diatoms, either in company or individually dominating samples, form verdant oceanic pasturage. $\times 150$.

LOWER: Sample of phytoplankton dominated by a single species, *Thalassiosira*, showing also a specimen of *Rhizosolenia* and one foreshortened disk representing perhaps *Lauderia*. $\times 150$.

(Both photographs from Bigelow, courtesy U. S. Fish and Wildlife Service.)

PLATE 3

- UPPER:** Sample dominated by the green algalike plant, *Halosphaera viridis*, with a few peridinians, *Ceratium longipes*, from a surface haul made off Shelburne, Nova Scotia. $\times 40$.
- LOWER:** Sample of midwinter phytoplankton from the inner part of Massachusetts Bay, dominated by the disklike diatom, *Coscinodiscus*, together with a few bristled *Chaetoceras*, peridinians, *Ceratium tripos*, and a few microcopepods. $\times 40$.

PLATE 4

- UPPER:** Sample of phytoplankton dominated by the oceanic diatom, *Chaetoceras densum*, a surface haul from the west side of the Gulf of Maine. $\times 150$.
- LOWER:** Sample of phytoplankton dominated by the slender rodlike diatom, *Rhizosolenia semispina*, including one specimen of a horned peridininian. From south of Martha's Vineyard. $\times 150$
- The diatoms in these two photographs show their specific adaptations for flotation, the *Rhizosolenia* by its slender, rodlike form and oblique ends, the *Chaetoceras* by its development of bristles and the formation of chains. (See p. 300.)
- (Both photographs from Bigelow, courtesy U. S. Fish and Wildlife Service.)

PLATE 5

- UPPER:** Rather monotonous sample of phytoplankton consisting almost wholly of the horned peridininian, *Ceratium tripos*, with occasional *C. fusus*, *Peridinium*, and some developmental stages of copepods. Surface haul from off Cape Cod. \times about 25.
- LOWER:** Sample of zooplankton dominated by herbivorous copepods, *Calanus finmarchicus* and other species, and euphausiid shrimps, *Thysanoessa*, with one glass worm. Taken in vertical haul from 100-0 meters, over the southwest slope of Georges Bank. $\times 4$.
- These photographs will give some idea of the relative size of peridininian pasturage and the grazers which feed upon it.
- (Both photographs from Bigelow, courtesy U. S. Fish and Wildlife Service.)

PLATE 6

- UPPER:** Sample of zooplankton dominated by the pelagic herbivorous euphausiid shrimp, *Thysanoessa longicaudata*, along with the copepod *Calanus finmarchicus*, two predaceous glass worms, *Sagitta elegans*, and one naked, shell-less pteropod mollusk, *Clione limacina*, relished by plankton-feeding whales when dominating the plankton. From a vertical haul from 100-0 meters off Shelburne, Nova Scotia. $\times 1.75$.
- LOWER:** Zooplankton dominated by the predaceous glass, or arrow, worm, *Sagitta elegans*, very destructive to copepods and the eggs and larvae of fish. From a vertical haul from 80 meters in Massachusetts Bay. $\times 1.75$.
- (Both photographs from Bigelow, courtesy U. S. Fish and Wildlife Service.)

PLATE 7

- UPPER:** Sample of an unusually rich catch of haddock eggs, including one of the glass worms, *Sagitta elegans*, known to prey upon them, a single pteropod mollusk, *Limacina retroversa*, and several *Calanus* and other copepods, from a surface haul over the eastern part of Georges Bank. $\times 4$. A single female haddock may spawn as many as 100,000 eggs.
- LOWER:** Sample of rather uniform zooplankton consisting almost wholly of the copepod *Calanus finmarchicus*, from a vertical haul from 30-0 meters in Massachusetts Bay. $\times 1.75$. (Compare with photograph of same species at higher magnification, pl. 9, lower.)
- (Both photographs from Bigelow, courtesy U. S. Fish and Wildlife Service.)

PLATE 8

UPPER: Sample of a chiefly herbivorous plankton community, largely copepods, the copepod *Calanus finmarchicus* predominating, with some *C. hyperboreus* and *Euchaeta norvegica*, and the euphausiid shrimp, *Thysanoessa*, together with several carnivorous forms—the glass worms, *Sagitta elegans*, the pelagic worm, *Tomopteris*, and two small jellyfish, *Aglantha*. From a vertical haul from 200-0 meters. $\times 1.5$.

LOWER: Sample of zooplankton consisting almost wholly of comb-jellies, the ctenophore *Pleurobrachia pileus*, with an admixture of barnacle larvae, *Balanus*, in the so-called free-swimming nauplius stage, taken in a vertical haul in 40-0 meters over Brown's Bank. $\times 1.5$.

(Both photographs from Bigelow, courtesy U. S. Fish and Wildlife Service.)

PLATE 9

UPPER: Sample of zooplankton dominated by juveniles of the amphipod *Euthe-misto*, a very voracious devourer of copepods and in turn the food of larger carnivores. A surface haul from the south slope of Georges Bank. $\times 9$.

LOWER: Sample of zooplankton consisting almost exclusively of the large copepod, *Calanus finmarchicus*, the most important of the small herbivores of the North Atlantic area. This is a portion of the most productive catch of *Calanus* yet made in the Gulf of Maine, a haul from which an estimated 2,500,000 copepods were taken off Cape Cod from 40-0 meters. $\times 9$.

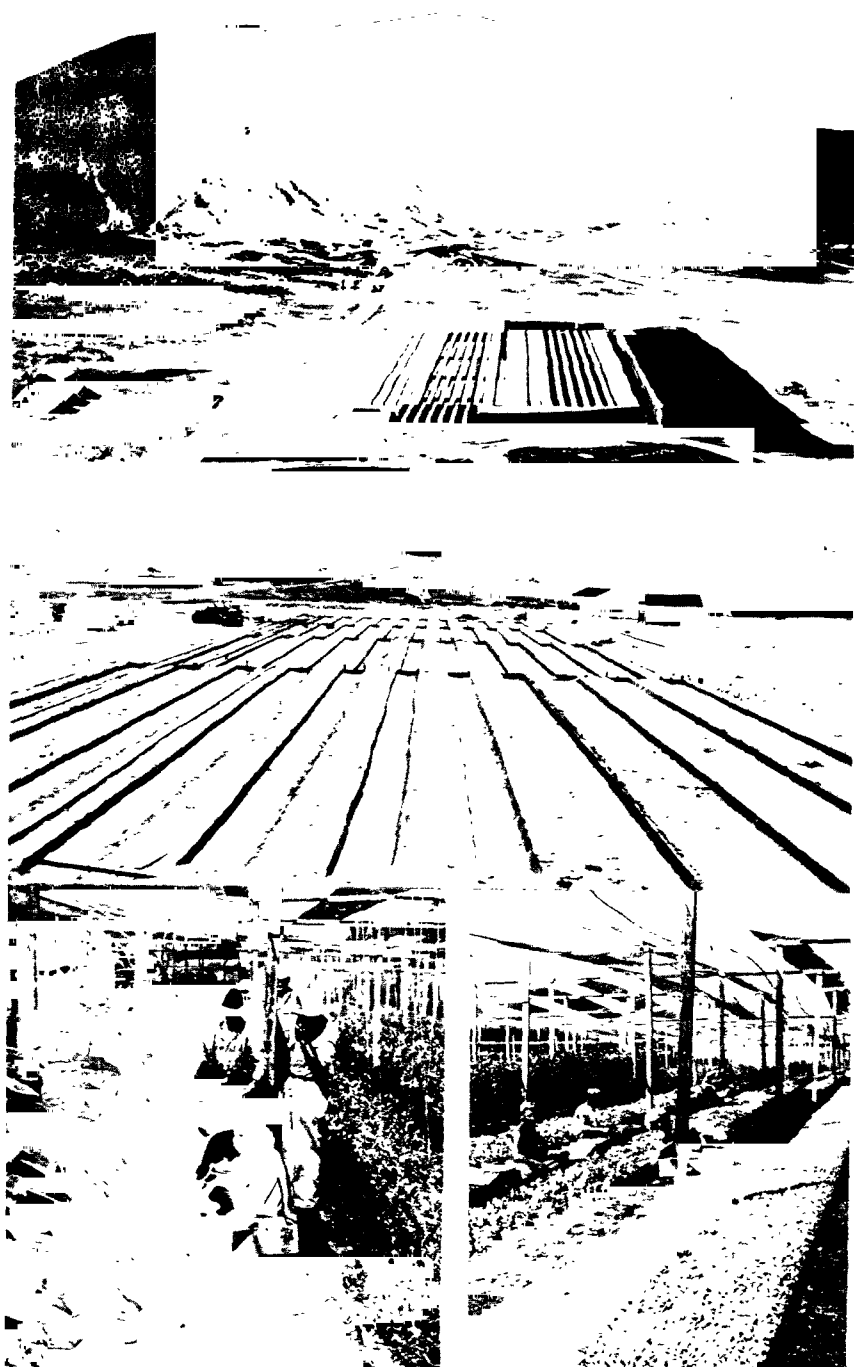
(Both photographs from Bigelow, courtesy of U. S. Fish and Wildlife Service.)

PLATE 10

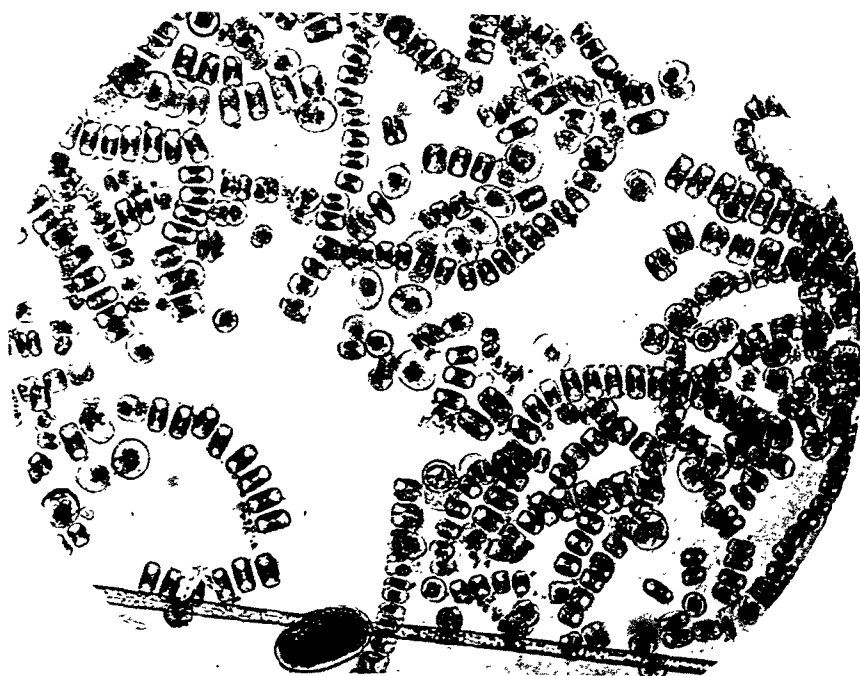
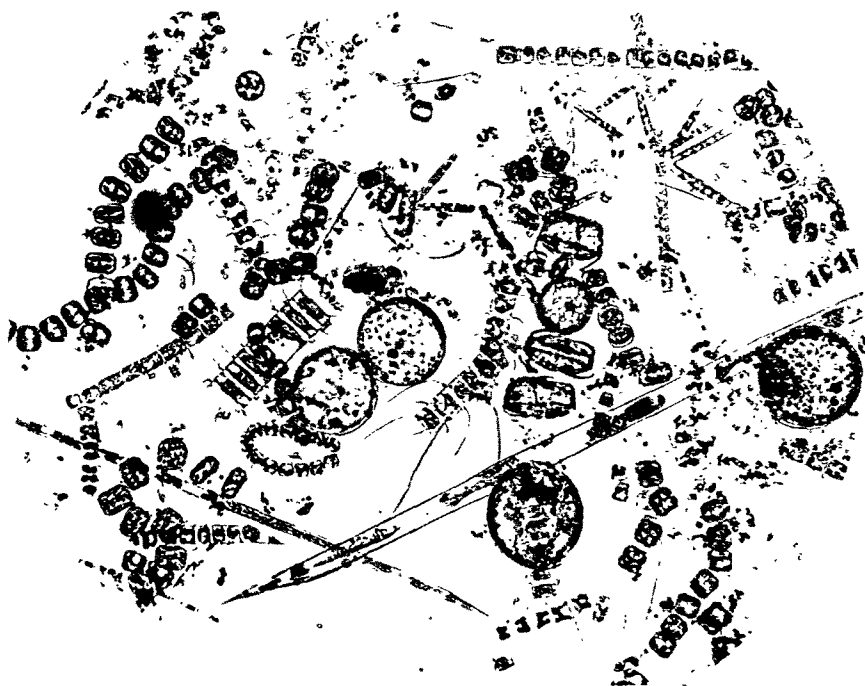
Food strainers of certain plankton-feeding fish and whales.

- a. Portion of branchial sieve of menhaden, *Brevoortia tyrannus*. $\times 25$.
- b. Portion of branchial sieve of herring, *Clupea harengus*. $\times 25$.
- c. Portion of branchial sieve of mackerel, *Scomber scombrus*. $\times 25$.
- d. Portion of marginal fringe of baleen plate of pollock whale, *Balaen-optera borealis*, from Gulf of Maine. Natural size.
- e. Portion of marginal fringe of baleen plate of finback whale, *Balaen-optera borealis*, from Gulf of St. Lawrence. Natural size.

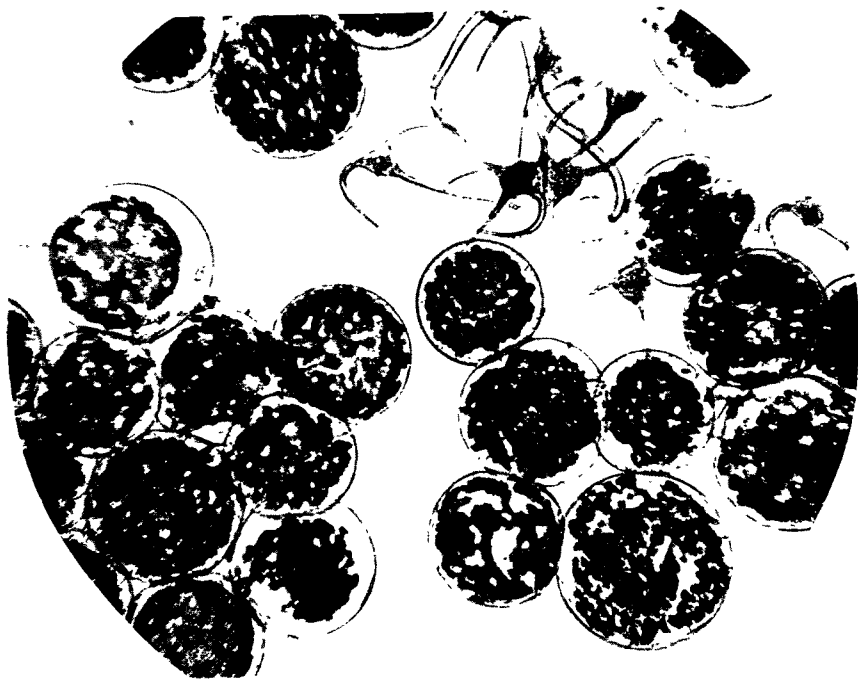
(From Bigelow, courtesy U. S. Fish and Wildlife Service.)



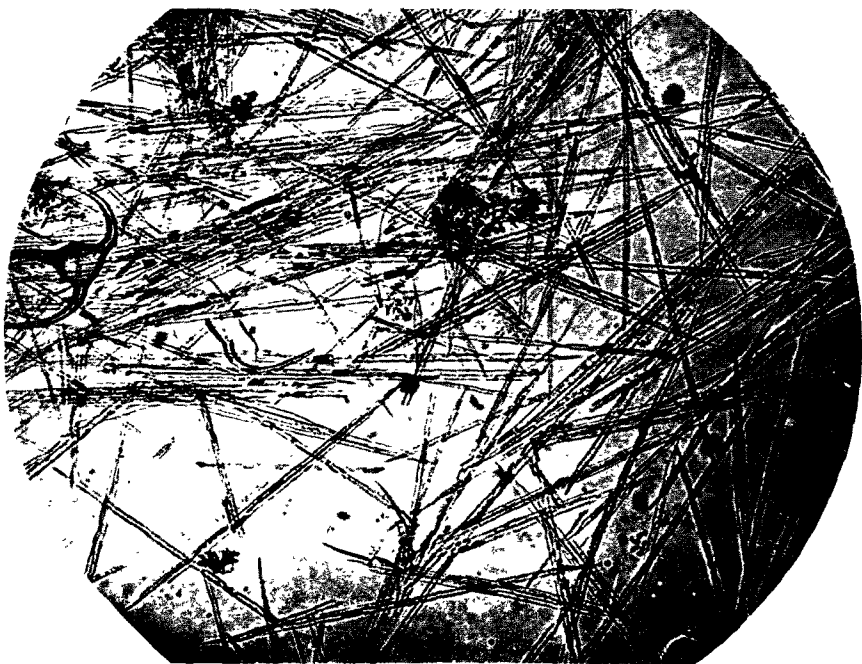
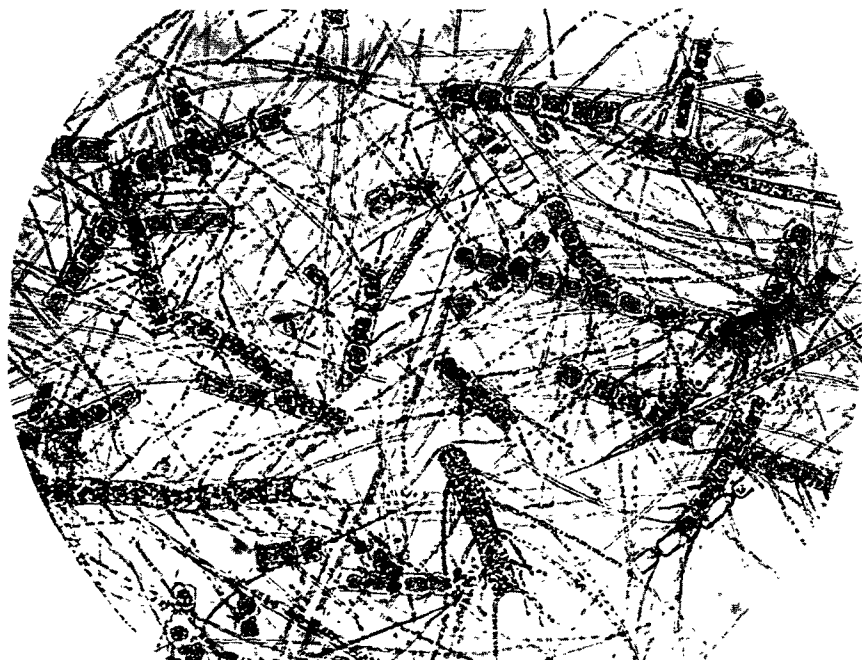
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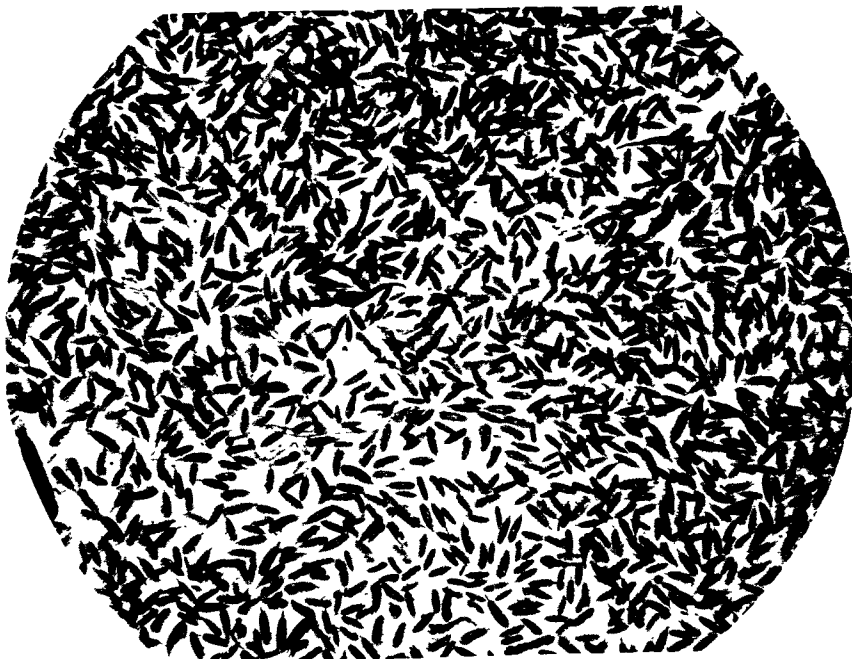
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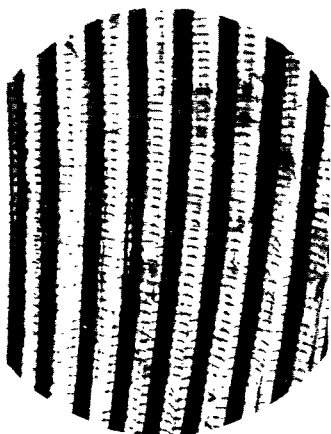
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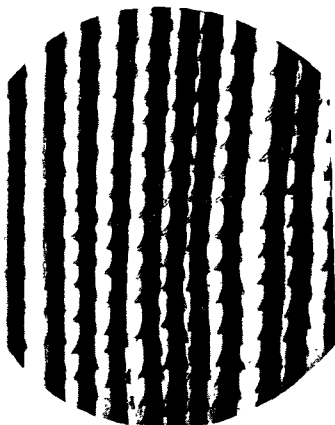
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a



b



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d



e

(For explanation, see p. 313.)

ANTHROPOLOGY AND THE MELTING POT¹

BY T. D. STEWART

Curator, Division of Physical Anthropology, U. S. National Museum

. . . America is God's Crucible, the great Melting-pot, where all races of Europe are melting and re-forming! * * * Here you stand in your 50 groups, with your 50 languages and histories, and your 50 blood hatreds and rivalries. But you won't be long like that, brothers, for these are the fires of God. . . . A fig for your feuds and vendettas! Germans and Frenchmen, Irishmen and Englishmen, Jews and Russians—into the Crucible with you all! God is making the American.

* * * the real American has not yet arrived. He is only in the Crucible * * * he will be the fusion of all races, perhaps the coming superman.—From *The Melting-pot: A Drama in Four Acts*, by Israel Zangwill.

INTRODUCTION

One of the outstanding phenomena in the field of human biology during the nineteenth century was the rapid population growth of the United States. By 1900 the population of continental United States had increased more than fourteenfold.² In Europe, by contrast, France had failed to double its population and Belgium alone had attained a threefold increase. Stating this comparison in another way, at the beginning of the nineteenth century every important European country, even including Spain and Turkey, exceeded the United States in number of inhabitants; whereas now only the U. S. S. R. has a larger population.

To a considerable extent this remarkable rate of population growth was due to an attendant phenomenon of human biology, remarkable itself for scale, namely, immigration. Between 1830 when it got well under way, and soon after 1920 when it practically ceased, over 38 million immigrants arrived in the United States. This accretion from foreign sources is about equal to the total population of our country in 1870 or to that of France in 1895. It is easy to see, therefore, why at the height of this period of immigration (1908) Israel Zangwill, the dramatist, was led to coin the metaphor "melting pot"

¹ Address of the retiring president of the Anthropological Society of Washington, delivered before the Society on the evening of Apr. 16, 1946.

² Such introductory statements are based on the census publications listed in the bibliography at the end.

and thus to characterize the United States as the place of the amalgamation of races and of mores.

Owing to the almost total cessation of immigration about 1920, our foreign-born are now as a whole a rapidly aging population. "Whereas in 1920 about 15 percent of their number were under age 25, the figure was only 4 percent in 1940. On the other hand, the proportion at ages 65 and older almost doubled within this period, from not quite 10 percent in 1920 to 18 percent in 1940.³

The growth of the population of the United States has been affected not only by a century of unprecedented immigration, but also by a differential birth rate as between foreign, native, rural, and urban elements. It is well known that the foreign-born at first had larger families than the native-born. Nevertheless, there has been a steady decrease in family size, both in the population as a whole (fig. 1) and also among the foreign-born (fig. 2). The average size of family in 1790 was 5.7 persons for the area covered by the census of that date; in 1900 it had decreased by 1 person (5.7 to 4.6), both for the area covered in the first census and for continental United States as a whole; and in 1940 it had decreased still further to 3.15.

That urban birth rates tend to fall below rural has been shown by the ratios of children under 5 years of age per 1,000 women aged 20 to 44. This ratio is known as "effective fertility." Between 1800 and 1930 for the United States as a whole this ratio dropped from over 900 to under 400. Yet in 1930 effective fertility for the farm population as a whole was over 500 and in one isolated county in Kentucky it was still over 900.⁴ The tendency of many foreign-born peoples to avoid rural areas and to congregate in cities may be a factor in the rapid lowering of their birth rate.

The net effect of these and other more involved factors is a gradual slowing down of population growth in the United States. According to a conservative recent prediction, made on the basis of the censuses up to and including that of 1940, the population of the United States should level off at around 184 millions about the year 2100 (fig. 3).⁵ This means that, if the present trend continues for another century and a half, natural growth will cause the population to increase only about 50 millions more.

Although we have seen the virtual end of immigration into the United States and are aware that the natural increase in the popu-

³ Statistical Bulletin, Metropolitan Life Insurance Co., June 1945.

⁴ See Lorimer and Osborn, 1934.

⁵ Back in 1919 Raymond Pearl and his associates fitted a logistic curve to the census counts from 1790 to 1910. Their prediction of the 1920 population proved to be in excess of the actual figure by 16 parts in a thousand; it missed the count in 1930 by 2.5 parts in a thousand (in defect); and it went wide of the mark in 1940 (37.3 parts in a thousand in excess). This error may have been due in part to the change in immigration policy. The latest prediction takes these trends into account.

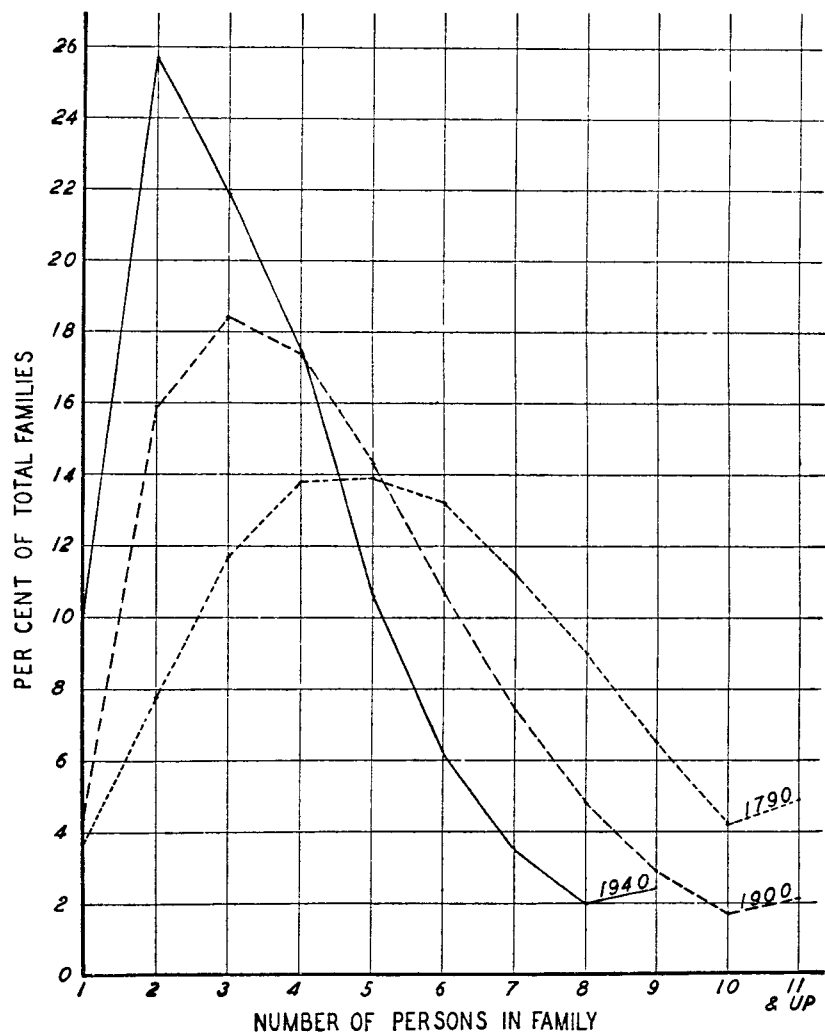


FIGURE 1.—Change in average size of families, 1790 to 1940. (Based on census figures for the respective years.)

lation is slowing, we know surprisingly little about the American physical type that is evolving. In support of this statement I shall review the racial elements that have entered into the American melting pot and also the efforts made by physical anthropologists to sample the product.

Americans, as Hooton has said, may be divided into five classes: 1, Real Americans, otherwise known as Indians; 2, Old Americans and 3, new Americans, both of whom have been born to Americanism; 4, immigrant Americans, those who have achieved Americanism; and 5, Afro-Americans, or those who have had Americanism thrust upon them. For lack of space the first and fifth of these classes will not be considered here.⁶

PEOPLING THE UNITED STATES

Before 1800.—Fortunately for our purposes, the national origins of the peoples coming to America, and accordingly the implications of their racial background, are well documented. This is due largely to the fact that a provision for census taking is included in the Constitution and consequently that the first census of the entire United States was taken in 1790, or nearly 10 years before the first census in any European country except Sweden. In this first census the names of the inhabitants were recorded, but not the places of birth. Hence, the proportions of the various European nationalities comprised in the population of the United States at that time have been worked out from inspection of the names. In general, 82.1 percent of the names are English, 7.0 percent Scotch, 5.6 percent German, 2.5 percent Dutch, 1.9 percent Irish, and all others less than 1 percent. Thus, although the early settlers were predominantly (91 percent) from the British Isles, there were goodly numbers of Germans and Dutch, and small numbers of still other nationalities. However, there was not a uniform distribution of these nationalities even at the beginning, for the Scotch show a concentration in Pennsylvania, Virginia, and the Carolinas; the Germans in Pennsylvania, Maryland, and Virginia; and the Dutch in New York.

Incidentally, the late Aleš Hrdlička designated the descendants of this early population as Old Americans, and this explains Hooton's use of the term as appears above. According to the original definition, Old Americans include those whose ancestors on each side of the family were born in the United States for at least two generations. At the time Hrdlička was working (1910–1924) this meant in general that all the ancestors on both sides of the family were in this land before 1830.

⁶ The situation as regards the American Negro has been summarized recently in a series of publications assembled by Gunnar Myrdal under the auspices of the Carnegie Institution.

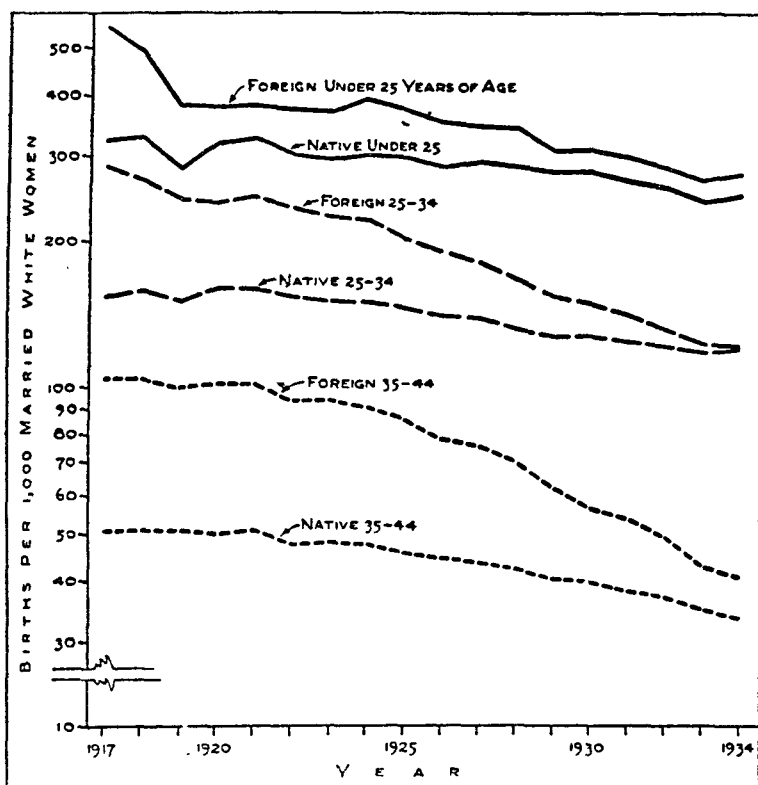


FIGURE 2.—Annual number of births per 1,000 married white women of specified age and nativity. Up-State New York, 1917-1934. (From Kiser, 1936, fig. 2.)

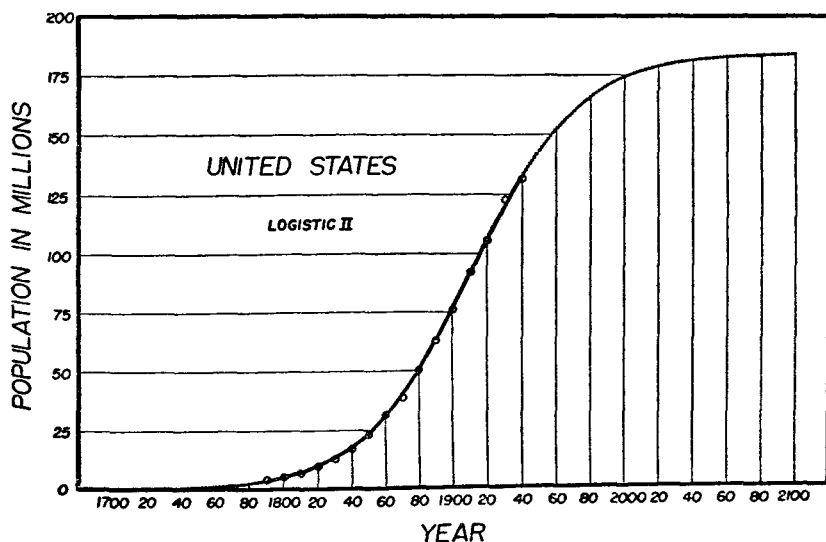


FIGURE 3.—Using the method of successive least square approximations, a smooth curve has been fitted to the census counts from 1790 to 1940, inclusive (given in circles). The dotted line shows the further extrapolation of the same curve. According to the prediction of this logistic curve, the population of the United States should stabilize around the year 2100 at about 184 millions. (From Pearl et al., 1940, fig. 2.)

After 1800.—To this early population, itself conceived through immigration and grown during 2 centuries to around 10 million, was added during the century beginning in 1820, as already mentioned, 38 million more through immigration. This stream of foreign-born varied in number and composition from year to year (fig. 4). In the fluctuations are mirrored the history of Europe and the United States during this period. The peaks show when America was most inviting and the troughs reflect the wars and depressions. And finally, after the immigration acts of 1921 and 1924 setting quotas went into effect, there is a rapid falling off in numbers. However, since the present quotas are based upon the numbers of the different nationals resident in the United States in 1890, that is, before the immigration from southern and eastern Europe got under way, they have insured that most of the small number now being admitted come from those countries that contributed the bulk of the early population.

Now it is one thing to know which nationals participated, and to what extent they are represented, in the great period of immigration, and another thing to know how these nationals have become distributed in the general population of the United States. Of course, there are well-known concentrations of foreign-born in various localities, such as Germans in Pennsylvania, Poles in Connecticut, Scandinavians in Minnesota, etc., but where else did these peoples go and in what numbers? Some idea of this distribution is given in the census recordings of the different nationalities by States. As an indication of what has happened to two of the foreign contingents (Irish, Italians), I have plotted on outline maps their numbers in percentages of the native white population and by three census years (1880, 1910, 1940). For example, in 1940 there were 3,408,744 native Whites in Massachusetts and only 114,362 foreign-born Italians. On the other hand, in 1880 the Whites in Massachusetts numbered only 1,320,291 and there were in the State at that time 226,700 foreign-born Irish. Thus, the relationship of these two foreign-born elements to the native white population may be represented by the percentages 3.35 (Italians in 1940) and 17.17 (Irish in 1880), respectively.

In using the native white population as a basis of comparison I have had in mind the population being affected by the immigrants. However, I realize that this gives a rather distorted view when the figures for 1880 are compared with those of 1940. This is owing to the fact that the native population has increased during this period. Because of this fact a group such as the Italians, that immigrated in large numbers only after 1890 (cf. fig. 4), does not show the concentrations of a group such as the Irish, that came in greatest numbers before 1890. In the example cited above, had the native white population of Massachusetts remained constant from 1880 to 1940 the Italians in

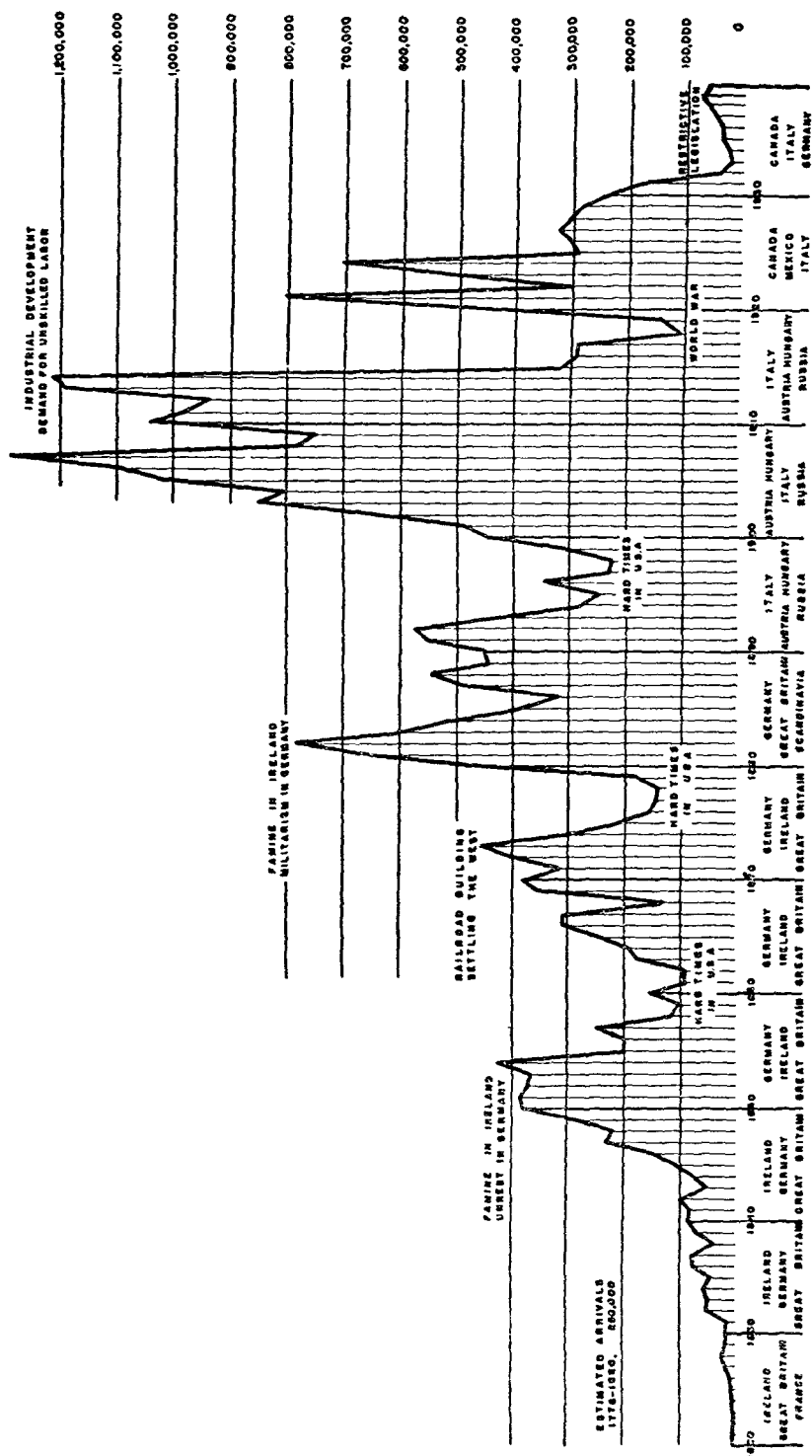


FIGURE 4.—Immigration to the United States from 1820 to 1940. Some of the causes of the fluctuations are indicated and the three leading nationalities in each decade are named. (Based on the reports of the Immigration and Naturalization Service.)

1940 would appear as 8.66 percent instead of 3.35 percent. Also, of course, if a State has a small native population, a relatively few foreign-born will show up as a high percentage, whereas in a populous State only a very large number of foreign-born will produce this same high percentage.

Glimpsing the record of each of these immigrating nationals in this way (figs. 5 and 6), which is comparable to looking at random frames from different moving picture reels, we get impressions of a repeated story varying in minor details. Essentially—and this is true also for English, Germans, Swedes, Poles, etc.—the same nationals have tended to go to the same parts of the country decade after decade, although the distribution differs for each. The northern and western European peoples, among them the Irish, came early, as already pointed out, and the southern and eastern European peoples, among them the Italians, came late. However, in both cases in 1940, nearly 20 years after immigration was drastically curtailed, few remain in the category of foreign-born. Henceforth the foreign-born will be a very minor element in census records.

Now, again, it is one thing to know where the foreign-born have settled and in what proportions, and it is quite a different thing to know what has become of their descendants—now native-born. In most cases, and certainly it is true of the descendants of northern and western Europeans, the second generation born in America is already indistinguishable culturally and physically from the descendants of Old Americans. Lacking stigmatizing foreign traits, there are few limitations on travel within the United States. Although we have no detailed records, we know that there has been an increasing internal migration in recent years. Using the State-of-birth data in the census reports, it is possible to learn not only the birth sources of the people living in each State, but also the destinations of the natives who had moved away from the State. The difference between those born out of a particular State who are living in it, and those born in the State who are living out of it, while not a complete measure of the net interstate migration, is a useful migration index. Obviously, depending upon the direction of this migration, the index may be positive or negative. The positive changes in population calculated in this way for the periods 1900–1910 and 1920–1930 are shown in figure 7.

During the last depression and again during World War II internal migration, especially to California, reached tremendous proportions. This is vividly illustrated by the following quotation from a popular news weekly:[†]

The westward wartime migration which had increased California's population from 6,907,000 to 9,000,000 by VJ-day was growing heavier. Despite the fact

[†] *Time Magazine*, April 15, 1946, p. 23.



FIGURE 5.—Foreign-born Irish in percentage of native-born Whites for the three census years 1880, 1910, and 1940. Black=10 percent and up; striped=5-10 percent; stippled=1-5 percent; and white=below 1 percent. The foreign-born were not reported for three States in 1880. Note early and continuous wide distribution of Irish (except in South) with concentration in States adjacent to the port of New York.

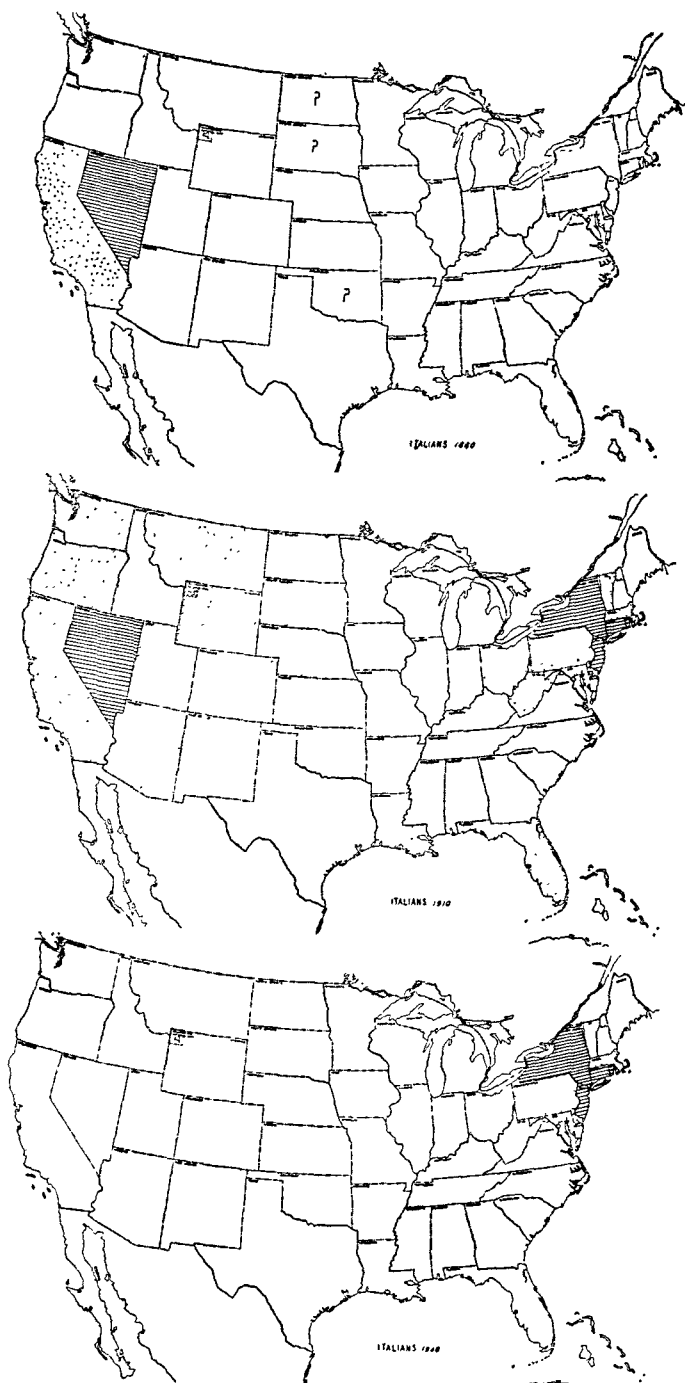


FIGURE 6.—Foreign-born Italians in percentage of native-born Whites for the three census years 1880, 1910, and 1940. Striped=5-10 percent; stippled=1-5 percent; and white=below 1 percent. The foreign-born were not reported for three States in 1880. Note that the Italians did not arrive in numbers until after 1880 and that they have tended to settle in the same places decade after decade (including parts of the South).

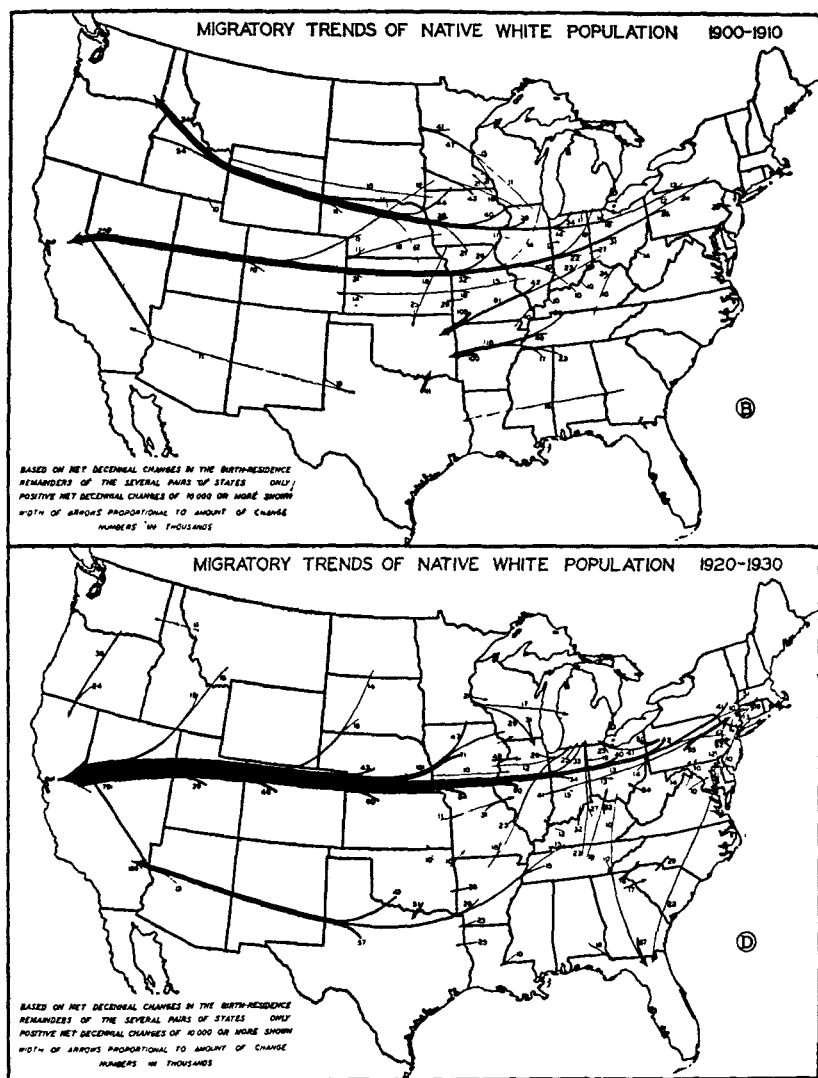


FIGURE 7.—Direction and rate of internal migration in the United States in two recent decades. (From Thornthwaite, 1934, pl. 6.)

that California was jammed to the last shack and trailer, 383,252 people had arrived by automobile alone in the first 2 months of the year. And they were no longer just the aged from Iowa, going west to die. Many were young and vigorous, their future bright before them. A wartime poll of service men stationed in California showed that 52 percent wanted to stay there.

Obviously this internal migration has served to break up and mix up many heretofore stabilized communities. One result of this is that both the latest foreign-born and the inbred descendents of the older foreign-born are marrying more and more out of their national groups. As long ago as 1931 in "An Ethnic Survey of Woonsocket, Rhode Island," Wessel found that, whereas in the first generation born in this country intermarriage amounted to only 12.1 percent, by the third (and 3/2) generation, it had reached 40.4 percent. She found also that "the Irish and British rank first in marrying out of their group. By comparison with these, French Canadians are slow to intermarry. Jews seldom intermarry." [P. 109.]

In this connection it is appropriate to return to the dramatist Israel Zangwill and to quote a pertinent statement which appears in the appendix to the 1914 edition of his play, "The Melting-pot":

[Religious] discords, together with the prevalent anti-Semitism and his own ingrained persistence, tend to preserve the Jew even in the "Melting-pot," so that his dissolution must be necessarily slower than that of the similar aggregations of Germans, Italians or Poles. But the process for all is the same, however tempered by specific factors. Beginning as broken-off bits of Germany, Italy or Poland, with newspapers and theaters in German, Italian or Polish, these colonies gradually become Americanized, their vernaculars, even when jealously cherished, become a mere medium for American conceptions of life; while in the third generation the child is ashamed both of its parents and their lingo, the newspapers dwindle in circulation, the theaters languish. The reality of this progress has been denied by no less distinguished an American than Dr. Charles Eliot, ex-president of Harvard University, whose prophecy of Jewish solidarity in America and of the contribution of Judaism to the world's future is more optimistic than my own. Dr. Eliot points to the still unmelted heaps of racial matter, without suspecting—although he is a chemist—that their semblance of solidity is only kept up by the constant immigration of similar atoms to the base to replace those liquefied at the apex. Once America slams her doors, the crucible will roar like a closed furnace. [Pp. 209-210.]

As we have seen, the door was slammed about 20 years ago. And available evidence seems to bear out this prediction: the process of racial amalgamation in America is speeding up; the crucible is roaring like a closed furnace.

STUDYING THE PRODUCT OF THE MIXTURE

For many years now physical anthropologists have been trying to discover the American physical type that is emerging as the product of the melting pot. To evaluate properly the studies made thus far it

is necessary to consider the European groups entering into the mixture.

Diversity in Europe.—As Boas pointed out in 1922:

It would be an error to assume that the intermingling of different European groups is a unique historical phenomenon which has never occurred before. On the contrary, all European nationalities are highly complex in origin. Even those most secluded and receiving the least amount of foreign blood at the present time have in past times been under entirely different conditions.

[For example] in Great Britain * * * there is * * * clear evidence of a large number of waves of migration. In prehistoric times we find a long-headed type, quite different in appearance and in customs from a later round-headed type. With the beginning of historic times we observe first Roman colonization, then waves of migration entering Great Britain from all parts of the North Sea, from Scandinavia and northern Germany, and, finally, the influx of the Normans. With this event extended migration ceased and the population of the island was gradually welded into the modern English.

The long continued stability of European populations which set in with the beginning of the Middle Ages and continued, at least in rural districts, until very recent times, has brought about a large amount of inbreeding in every limited district. [Pp. 181-182, 184.]

Because of such a history, Europe's peoples present great physical diversity. For instance, stature varies on the average in different parts of Europe over 7 inches, the tallest people being in the north and west (fig. 8); head shape varies over 15 index units, the roundest heads being in the south-center and east (fig. 9); and pigmentation ranges all the way from light blond to dark brunet with corresponding stratification from north to south (fig. 10). Accordingly, the early immigrants into the United States, being from the northern and western parts of Europe, were predominantly tall, long-headed blonds; whereas the later comers, being from the southern and eastern parts, were mostly short, round-headed brunets. Of course, there are exceptions to this generalization.

STUDIES UNDER GOVERNMENT AUSPICES

Immigrants.—Here in America comparatively little effort was made to study the immigrants on arrival. During 1908-9 Boas undertook to investigate the physical characteristics of immigrants for the United States Immigration Commission. A total of 17,821 subjects from 3 years of age and up were measured. These were divided into national groupings. Since there were over 700,000 immigrants admitted in 1908 and again in 1909, and about 30 national groups of Europeans are recognized by the Immigration Commission, it will be seen that Boas' sample was pretty small.⁸ Nevertheless, this small sample led Boas to an important biological discovery, namely,

⁸ In 1913-14, through Hrdlička's efforts, some measurements were taken on immigrants arriving at Ellis Island. The number examined scarcely exceeded 500. Average measurements divided into 12 national groups are listed in Hrdlička's "The Old Americans" (1925).

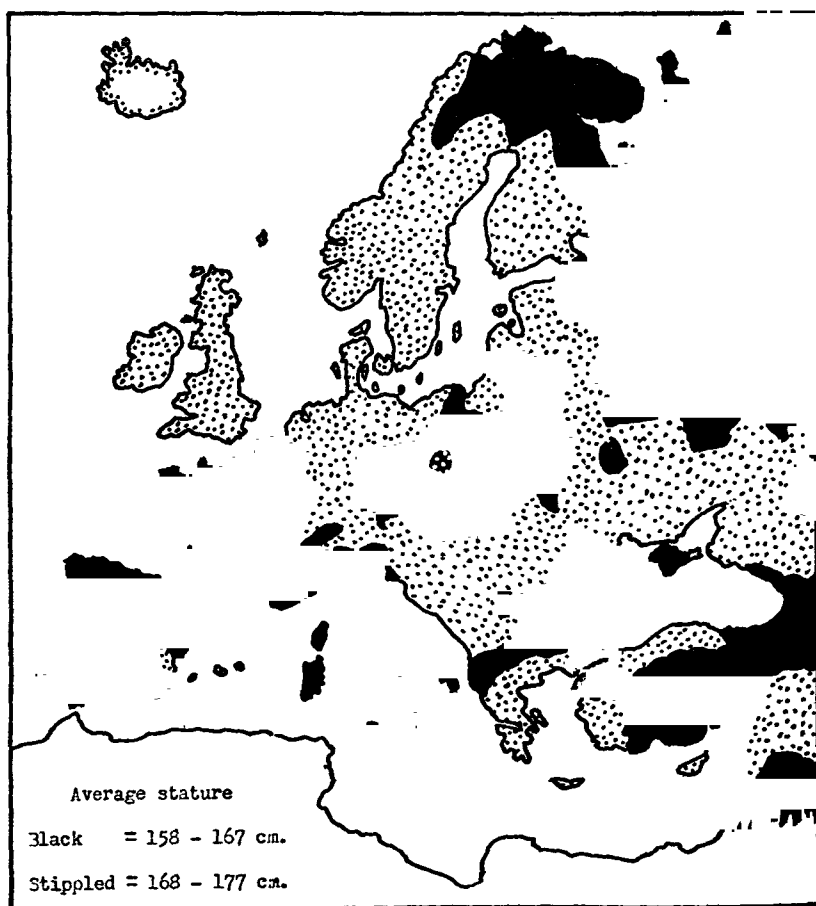


FIGURE 8.—Approximate distribution of the shortest and tallest peoples in Europe.
(Modified from Coon, 1939, map 5.)

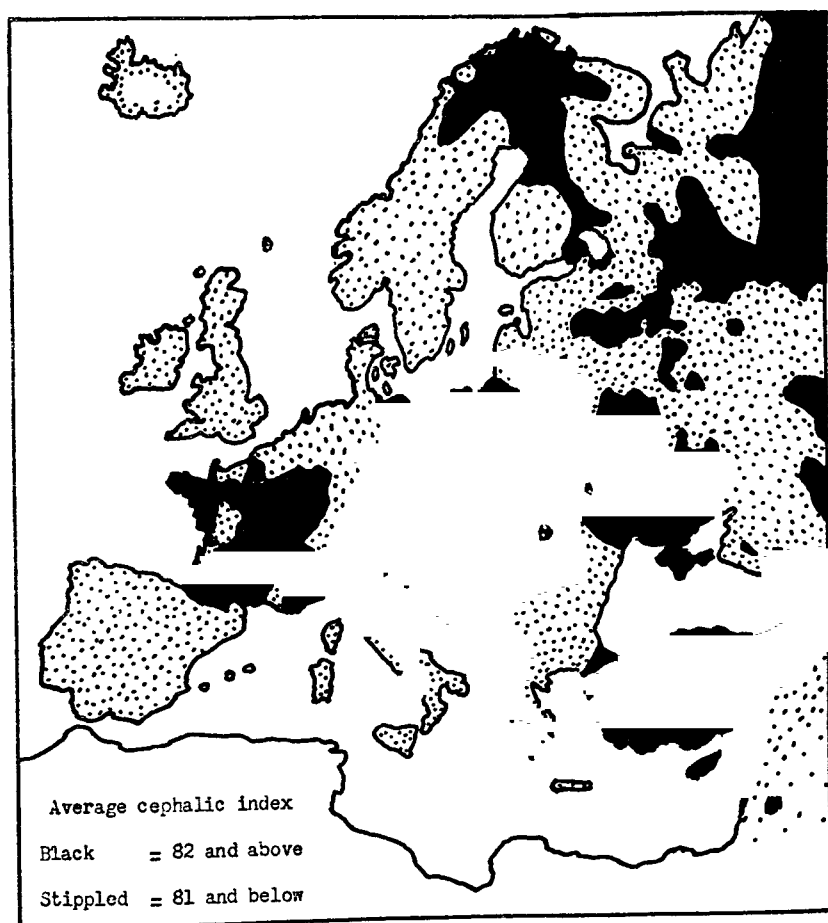


FIGURE 9.—Approximate distribution of head shape (round heads and long heads) in Europe. (Modified from Coon, 1939, map 6.)

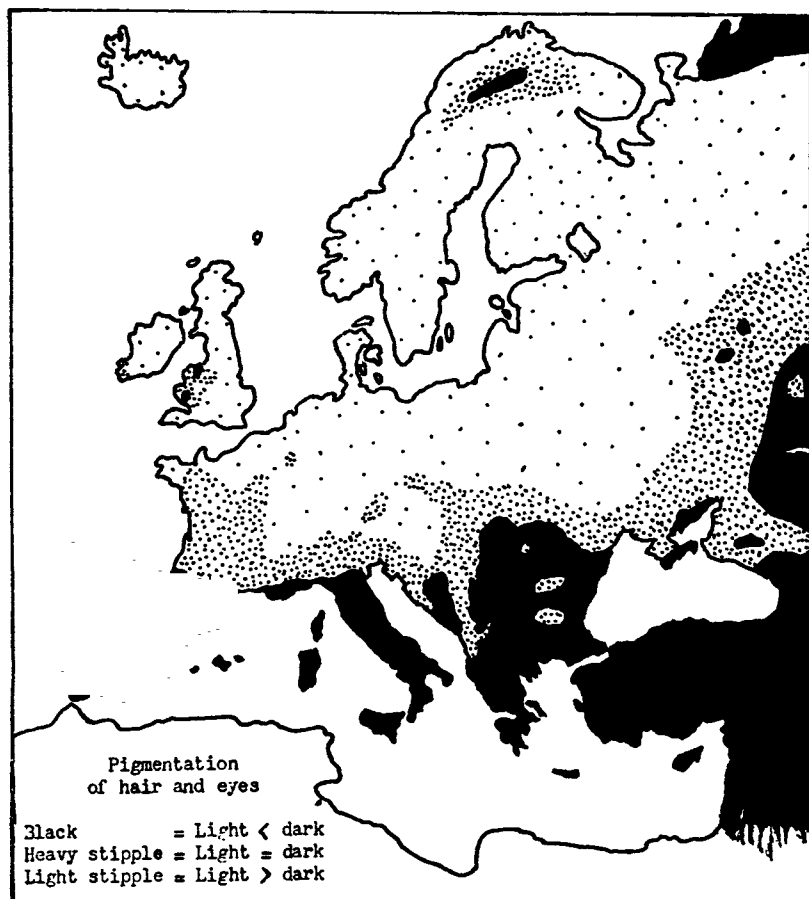


FIGURE 10.—Approximate distribution of light and dark pigmentation in Europe.
(Modified from Coon, 1939, map 8.)

that the bodily form of the descendants of the immigrants was different from that of the immigrants themselves. He said:

It appears that the longer the parents have been here, the greater is the divergence of the descendants from the European type.

These results are so definite that, while heretofore we had the right to assume that human types are stable, all the evidence is now in favor of a great plasticity of human types, and permanence of types in new surroundings appears rather as the exception than the rule. [1912, pp. 5, 7.]

Incidentally, it should be noted that, owing to the dates of the work by Boas and Hrdlička, the immigrants available to them for study were mostly from the southern and eastern parts of Europe.

Soldiers.—World War I yielded as one of its useful byproducts some measurements of the men drafted into the Army and also of those later demobilized. Because of the conditions of the draft, the Army necessarily included some recent immigrants and descendants of older immigrants. Analysis of these measurements by districts, therefore, gives a partial indication of the physical variation in the different parts of the country. The variation in stature among the first million recruits is shown in figure 11. In general, the areas of tallest stature are those least affected by recent immigration. The distribution of short stature is about what would be expected from the data already presented on immigration. Unfortunately, such data as were obtained during the Civil War were restricted to the northern States, and those for World War II are reported to have been destroyed.⁹

In passing, some comment should be made on the limitations of the Army for anthropometric purposes. Such a group represents only the healthy young men within certain age and size limits. Obviously, therefore, it is not a random sample of the population. Also, the measurements taken thereon are quite restricted in number and are not always taken carefully. Even the additional measurements on 100,000 soldiers taken at demobilization in 1919 under the direction of anthropologists have the same limitations as to sample and moreover were intended for tailoring rather than for biological purposes.

Clothing standards.—The mention of tailoring leads us naturally to another Government anthropometric project, namely, that carried out by the United States Department of Agriculture for garment and pattern construction.¹⁰ The data used in the industry for the construction of clothing have grown up apparently chiefly by trial and

⁹ Personal communication from Dr. George D. Williams, formerly in the Vital Records Division, Office of the Surgeon General. For Army anthropology see the reports by B. A. Gould (1869), Baxter (1875), and Davenport and Love (1921).

¹⁰ The project was under the direction of Miss Ruth O'Brien, Textiles and Clothing Division, Bureau of Home Economics, and was carried out in cooperation with the Work Projects Administration.

error, based upon measurements taken on a few individuals by various inaccurate procedures. To remedy this situation the Department of Agriculture has undertaken to provide reliable measurements of an adequate sample of the population. So far only women and children have been studied. The women number 14,698, which is a very small proportion of the approximately 45 millions in the country. Also, only 7 States (Arkansas, California, Illinois, Maryland, New Jersey, North Carolina, Pennsylvania) and the District of Columbia are represented. By reference to figure 11 it will be seen that all these States, except Arkansas and perhaps North Carolina, are in the low-stature area. Thus, although this study has attempted to get a random sample, it has not wholly succeeded. Moreover, since the emphasis here is on tailoring, relatively few of the measurements are suitable for general comparison.

Old Americans.—One more anthropometric project carried out under a Government agency may be mentioned. This is the study of Old Americans by Aleš Hrdlička of the United States National Museum. At the time this study was undertaken conflicting views were held regarding the nature of the earlier comers to this country as well as their successors up to the time when immigration assumed large proportions. These uncertainties could be resolved, Hrdlička believed, by examining the descendants of this early population.

The term "Old American" has already been defined. If used in the strict sense that all the ancestors on both sides were in this land before 1830, obviously the group is fast disappearing. As Hrdlička says:

In the beginning of the studies it seemed desirable to make the limit of four, or still better five, generation Americans; but on trial this was found quite impracticable. When the eastern and southern communities, where considerable inbreeding has taken place and the subjects from which would obviously not be the most desirable for our purposes were excluded, it was found that those who could qualify to four or five generations of pure American ancestry on both sides were astonishingly scarce, and that also, on the whole, they represented rather too much of social differentiation. Even those of three generations pure native ancestry are far less common than might at first be imagined. [1925, p. 5.]

Since this work was carried out with maximum precision and with the biological point of view, it furnishes a useful description of a selected element of the American population. Although the Old Americans examined by Hrdlička had a limited geographical distribution and the total did not exceed 2,000, his results have been confirmed by Bean and Carter.

Incidentally, a comparison of stature between the Old American females and the Department of Agriculture garment-series females shows the latter to be the shorter by nearly 1.5 cm. (161.85 vs. 160.42). This is probably due to the foreign element in the latter less selected series.

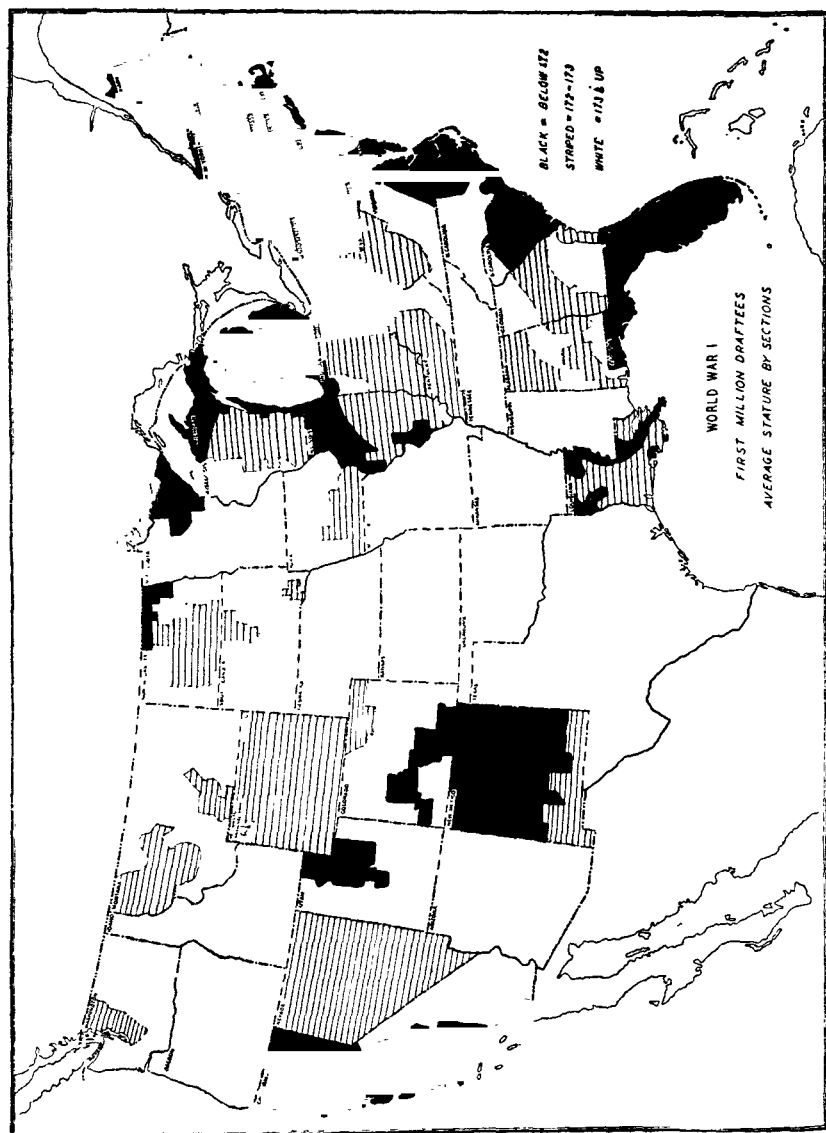


FIGURE 11.—Distribution of stature in the United States as revealed by measurements on soldiers of World War I. (Prepared from data supplied by Davenport and Love, 1921, pl. 5 and table 21.)

STUDIES UNDER THE AUSPICES OF OTHER INSTITUTIONS

Students.—Outside the Government, the main anthropometric studies on the American people have come from colleges and universities. In general these studies have been based upon the entrance physical examinations of students. The reports are very numerous, but only a few have received thorough analyses.¹¹ However, all have served to call attention to the secular changes taking place in this element of the American population. By comparing year by year the dimensions of students of the same age, it has been discovered that size is increasing. Studies made in New England colleges by Bowles and involving father-son and mother-daughter combinations show the changes illustrated in figure 12. It is now known that this is a part of a world-wide phenomenon and it has been suggested that it is due to nutritional changes or perhaps may be evolutionary in nature.¹² We have seen already that Boas detected such changes in immigrants. Obviously, this secular change, regardless of its explanation, serves to confuse the picture as to the developing American type.

Criminals.—In addition to the work on students, a broader attack on the problem of the developing American type has been undertaken at Harvard by Hooton and his students in the Department of Anthropology. Their approach has been through criminals and such civilian groups as could be measured in Boston and at A Century of Progress Exposition held in Chicago in 1933-1934. A total of about 17,000 persons were examined. Commenting on their composition, Hooton says:

Our series represent fairly large samples from three markedly diverse levels of our population. The criminals are socially, economically, and biologically the most debased element. The Boston civilian check sample is composed, for the most part, of urban residents representing a respectable working-class population, which has enjoyed, presumably, few of the advantages conferred by wealth and by social position. The Century of Progress series proves to be a group of persons disproportionately selected from the highly educated, and, on the whole, economically and socially superior classes. Undoubtedly this selection arose from the situation of the Harvard Anthropometric Laboratory in the Hall of Social Sciences. Probably few persons visited this hall intentionally unless they happened to be interested in education and in social problems. It required a certain intellectual curiosity and a certain pertinacity for these persons to book and to fulfill engagements for anthropometric examinations. If the laboratory had been operated in the part of the Exposition known as "The Streets of Paris," the character of the sample studied might have been somewhat different. [1936, pp. 25-26.]

The method of analysis used by Hooton was that of sorting out arbitrary combinations of racial criteria and assigning to them names

¹¹ See especially the publications by Bowles (1932: Harvard), H. N. Gould (1930-1939: Newcomb), Jackson (1927 and 1929: Minnesota), and Steggerda et al. (1929: Smith).

¹² See articles by Andrews (1943) and Stewart (1943).

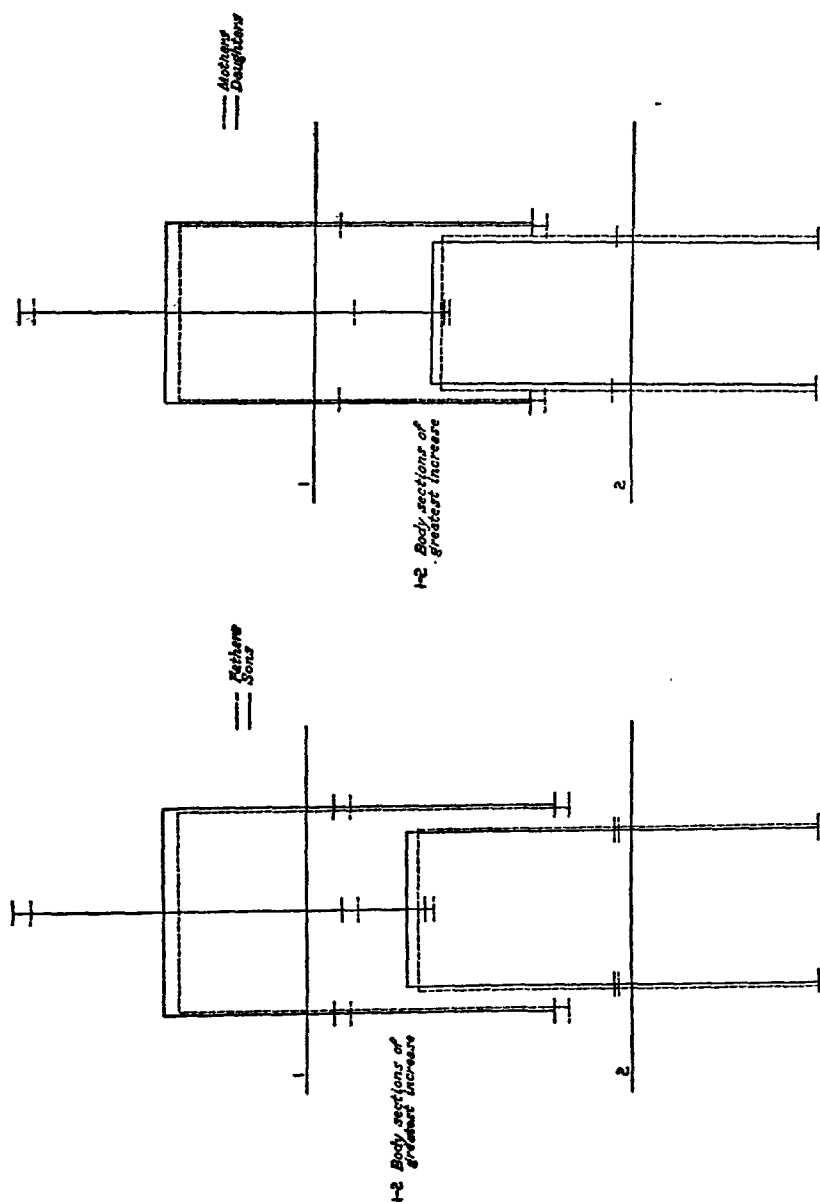


FIGURE 12.—Increases of various body parts of sons and daughters over fathers and mothers, respectively, as revealed by records of New England colleges. (From Bowles, 1932, figs. 6 and 14.)

of European racial types having like physical characteristics. Among the type designations are Mediterranean, Nordic, Alpine, Dinaric, etc. When these "imperfectly segregated and classified physical types, called by courtesy 'racial' types," were sorted out of his three widely divergent series, Hooton found that their proportions were practically identical. He feels it is a very remarkable fact "that these types should show individually certain consistencies of a sociological nature, certain occupational and educational resemblances, whether they are drawn from the cream of the population, from the middle of the draught, or from its very dregs" (p. 26). Unfortunately, he does not seem to have followed up this finding to see whether it is an accident of sampling or indicative of the state of amalgamation in the melting pot. Yet inspection of the stature of criminals by States shows the same distribution as noted for soldiers of World War I; that is, for example, low in Massachusetts and high in Texas.

Racial islands.—In all the foregoing, no mention has been made of anthropometric studies on communities here in America where European national elements still live in pure form and tend to inbreed rather than interbreed with other groups. Strange as it may seem, although such groups are common knowledge, almost no effort has been made to study them. An exception is the work of Steggerda on the Dutch of Holland, Mich., carried out while he was with the Carnegie Institution. Unfortunately, although suggesting an increase in size for the Dutch born in America, this work was not altogether conclusive, perhaps on account of the inadequate numbers used (130).

Another such group that has been studied is the Acadian French in Louisiana. Harley Gould found that the 100 men he examined were intermediate between Old Americans and the Acadian French of Canada. In other words, this French element in the United States has undergone some amalgamation.

Insurance records.—Finally, mention should be made of the routine physical data assembled by insurance companies. The population coverage presented by the insured is almost all that could be desired. However, the records include only two useful physical measurements, stature and weight, and these are taken carelessly. Stature includes shoes when actually measured and probably often represents a guess; weight is taken with clothing. Thus far the insurance companies have been deaf to the plea of the American Association of Physical Anthropologists for a reform of technique. A simple change here would give an invaluable check on a fundamental biological problem.

DISCUSSION

This review proves, I believe, as stated in the beginning, that we know surprisingly little about the new American physical type. The vagueness and evasiveness of the pronouncements regarding the evolving

type made by those engaged in its study only serve to emphasize this point. For example, Hrdlička (1926), after studying the Old Americans, concluded that

The observations show, in general, that the unmixed descendants of the older stock of Americans do present already an approach toward a physical type which may be called "American." With this type there still occur fairly numerous individuals of both sexes who through persistence or reversion show distinctly one or the other of the older types which have entered into the composition of the nationalistic groups that have built up the American. But in a fair majority of the Old Americans these older types are more or less obscured and a new and somewhat differing type, an American type, is apparent. [P. 101.]

[The product of the melting pot,] through ever-increasing intermixture, may doubtless in the course of a few generations be expected to approach a newer blend—the American type of the not far distant future. This type, we may surmise from all the available data, will not be far from the Old American type of the present, and yet will be somewhat different, particularly in physiognomy and behavior.

This Neo-American type will in all probability be, in the average, tall, more sanguine, and perhaps less spare than the old. It will remain essentially an intermediary white type in pigmentation, head form, and other respects. It will show for a long time yet a rather wide range of individual variation in all respects. And it may well be expected to be a wholesome and effective type, for mixtures such as those from which it shall have resulted are, so far as unbiased scientific research shows, not harmful but rather beneficial, and conditions of life as well as environment in this country are still favorable. [Pp. 102-103.]

Hooton (1936), in discussing the status of the American, raised a number of questions requiring elucidation. Among these is the following: "Do the acclimatized Americans differ from their European forebears and have they amalgamated into new biotypes?" Significantly, Hooton speaks of "new biotypes" rather than "a new biotype." Apparently this question anticipates the results of his type analysis (see pp. 334-336), since nowhere does he consider an over-all type. However, he goes on to say that a complete and conclusive answer to this question

* * * must await the gathering and analysis of far more data than are available at present. This lack of adequate information cannot be attributed solely to the apathy, incompetence, or paucity of physical anthropologists. It is due rather to an apparently inherent revulsion from honest self-examination which afflicts men as individuals and which expresses itself in governments by a settled policy that it is folly to be wise in the matter of the anthropological composition of its citizenry. [P. 2.]

One other example of how the evolving American type appears to an anthropologist may be cited. In a recent discussion of anthropometric studies on the American people Shapiro (1945) ends on this note:

It may well have occurred to the reader by this time to wonder how far the American people are evolving a characteristic American type fundamentally distinct from those of our European contemporaries.

The American of today remains a close derivative of the stocks that have settled here, but he has at the same time undergone modifications from his ancestral types. His deviations from European norms are either the results of mixture among the various representatives of Old World types or the consequence of an increased size with the attendant changes in bodily proportion that follow on such a quantitative expansion. [P. 255.]

Obviously, these writers have said about all that our present knowledge warrants saying about the evolving American type. The rate and kind of change in the physical appearance of our population is largely unknown. Thus far this problem has not been tackled directly. Except possibly in the case of the Army, physical anthropologists have not raised their sights to the nation as a whole. The few students who have entered this field have restricted their efforts to small selected samples. This does not mean that these special studies have not yielded much of value to human biology. Optimistically perhaps they can be compared to the pilot plants of new industries.

Since the white population is now approaching 120 millions, it is too vast a subject to be studied by individuals. Only the Government or an institution with large resources can handle the subject properly. Ideally, physical observations should be made on the population by physical anthropologists in connection with at least every third national census. This interval would permit some continuity of direction.

The Government, naturally, has been reluctant to take up this type of survey, because the utilitarian objectives have not appeared sufficient to warrant the required expenditure of public funds. This is the reason that physical anthropologists, seeking extra measurements on the Army, have had to disguise themselves as tailors. The people have not questioned the money spent to improve the fit of their sons' uniforms.

Yet a good case can be made for the utility of periodic surveys of the American population. The fit of clothing, which has already received some attention, as we have seen, needs much more study. Secular changes in physical size may well lead to periodic adjustments in patterns.

A few other reasons for this type of study can be pointed out briefly. It is an accepted fact that some physical types are better insurance risks than others. For instance, insurance companies report that, in general, life expectation decreases as body weight increases. This is probably a very crude generalization, because, as already pointed out, life insurance companies have little information on body types for purposes of such correlations. On the other hand, studies made during the recent war on young men showed that types with somewhat of a feminine body build could not achieve a high level of physical fitness. This information was useful in the selection of men for dif-

ferent military roles and might be more generally applied. Again, clinical studies point to a high correlation between body build, or constitution, and such things as gastric ulcers, gall-bladder disease, arthritis, certain major psychoses, etc. This information is being applied in clinical diagnosis.¹³

To the general field of body build, or constitution, physical anthropologists have been giving considerable attention of late. Descriptive techniques are rapidly being perfected. Because photography is being utilized in this connection, it is possible to make an accurate record speedily. Such techniques carry high promise for national surveys such as we are considering.¹⁴

Life Magazine ¹⁵ recently carried pictures of Hooton measuring people for the purpose of getting specifications for a car seat that would more nearly accommodate the general public in greater comfort. Public seating, like ready-made clothing and anything else mass-produced to meet the needs of all types of human bodies, has been a hit or miss proposition. The public has suffered from this lack of knowledge of the human form.

During World War II the Army Air Forces was forced to take this problem into consideration. More and more gadgets were being crammed into planes without corresponding adjustments for the size of the men who were to operate them. Also, helmets and oxygen masks were being produced with very little regard for the variations in the head sizes of the men who were going to wear them. Physical anthropologists remedied this situation by measuring a sample of the fliers and producing manikins to which machines and equipment could be adjusted.¹⁶

Wider application of physical anthropology in peacetime industry promises to be of great benefit to the American people. If this materializes, there should be a rapid increase in our knowledge of physical types in America. Yet I venture to doubt that commercial interests will supply data on a scale sufficient to define the over-all American type, much less to follow its development. Commercial interests will be content if they can produce something better than exists at the moment; or at least if they can advertise it as better.

Human biology probably will gain most if the problem is tackled by an agency which is not seeking profit. In this connection it is encouraging to note that Hrdlička willed a sum of money to the National Academy of Sciences for periodic surveys of the American people. Perhaps this gift to pure science, from a man who was himself

¹³ See the publications by Draper et al. (1944), Heath (1945), and Woods et al. (1943).

¹⁴ Sheldon (1940) has developed a technique that he calls "somatotyping."

¹⁵ Feb. 11, 1946, pp. 33-36.

¹⁶ A general account of the physical anthropology in the Army Air Forces has been published by Damon and Randall (1944).

an immigrant and who, as a pioneer in physical anthropology, was intensely interested in the product of the melting pot, will provide a means for its further study.

ADDENDUM

Since this was written Alice M. Brues of Harvard University has published ¹⁷ an analysis of measurements taken during the war on 3,075 enlisted men at Camp Sibert, Ala. By classifying each individual according to his principal national extraction and State of birth, she was able to identify five outstanding types: 1, A tall, thin-faced, narrow-headed type, commonest in those of British extraction and typical of the South. 2, A type, tall like the first, but with wider face and head. This is typical of Scandinavian extraction and is common mainly in the west north-central States. 3, A short type, round-faced and with a broad head, typical of Germanic, Russian, and Slavic extractions and common mainly in the middle Atlantic and east north-central States. 4, A type, short like the third but with narrower face and head. This is typical of French and Mediterranean extractions and common in New England. 5, A type distinguished mainly by an unusually broad face, out of line with any of the European extractions. This type, indicative of Indian admixture, occurs mainly in Oklahoma and Texas.

The significance of this finding is that this sample of the present-day population shows clear local differences in physical appearance reflecting the various European nations from which its ancestors came. From this it would seem that a stable "American race" is still a thing of the remote future.

Incidentally, Dr. Brues has shown that intelligent handling of a small sample can furnish considerable information on the progress of the melting pot. This simple method should facilitate future testing.

Mention should be made also of the United States Army Anthropometric Survey carried on during 1946 through the Research and Development Branch, Military Planning Division, Office of the Quartermaster General. This project was directed by Francis E. Randall and set its goal at 100,000 males and 10,000 females. Although these figures were not quite reached, and although clothing design largely controlled the selection of the measurements, it was possible to include much of general anthropological interest. Also, the usefulness of this survey has been increased by photography directed toward somatotyping. It is to be hoped that the analysis of these data will further clarify the product of the melting pot.

¹⁷ Brues, Alice M., *Regional differences in the physical characteristics of an American population*. Amer. Journ. Phys. Anthropol., n. s. vol. 4, No. 4, pp. 463-481, 1946.

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ARCHEOLOGY OF THE PHILIPPINE ISLANDS

BY OLOV R. T. JANSE

[With 15 plates]

The Philippine Islands have been in bygone days one of the cultural crossroads of the Pacific. In spite of the interest shown in many quarters to further, by means of archeological excavations, our knowledge of the ancient civilization of these islands and the cultural currents that have passed through them, so far only sporadic efforts have been made in that direction. There does not yet exist in the Islands an effective central organization responsible for the direction, supervision, and coordination of such research,¹ which could be compared, for example, with the archeological survey of French Indochina, *L'Ecole Française d'Extrême-Orient*, founded about half a century ago by President Paul Doumer, while he held the position of Governor General. This organization has not only served as a training ground for French Orientalists of world renown, but has gradually become, through its research activities, its field work, and its publications, one of the foremost centers for the promotion of our knowledge concerning the origin and development of the great civilizations of Asia. Other such organizations have been successfully developed in India, the East Indies, and elsewhere in the Far East.

The few collections of pre-Spanish antiquities in the Philippines consist principally of Chinese ceramics. As in many instances, no records have been kept concerning the circumstances under which the objects were found, their documentary value is considerably weakened and they are partly to be regarded as curiosities. It is also regrettable that so little has been published concerning excavations carried out under scientific control.

The late President Manuel Quezon was eager to remedy this situation and to have young Filipinos trained to organize and direct an efficient archeological survey. While conducting archeological excavations in the Philippines, sponsored by Harvard University, the writer was granted an audience by President Quezon in December

¹At the time of the American intervention, plans were conceived for such research, but not carried out. See H. W. Krieger, *Peoples of the Philippines*, Smithsonian Institution War Background Studies No. 4, 1942.

1939, when he was given an opportunity to explain to the Chief Executive the aims of our field work and their implications. The President not only consented to support our work actively, but authorized the writer to make an extensive tour in the Philippines from Luzon in the north to the Jolo Islands in the south, and to conduct a preliminary investigation regarding more extensive archeological field work, and also to make suggestions for the creation of a national archeological survey. The President also indicated his willingness to grant generous financial support if such an organization could be established. However, as the political situation in the Far East grew darker and darker, the project had to be shelved temporarily, and the writer left the Philippines for the United States in August 1940. When the new Republic has managed to overcome its present economic difficulties and urgent material needs, it appears likely that the creation of a national archeological survey will again be brought under consideration.

PROBLEMS OF PHILIPPINE ARCHEOLOGY

Because of their situation in the Pacific, the Philippines present a great many archeological problems ranging in time from the Stone Age up to the earliest Spanish intervention in the sixteenth century—problems which concern not only the Islands themselves, but also neighboring countries. As the Philippines still present an almost virgin soil, as far as archeological field work goes, it is as yet impossible to grasp the multiplicity of problems regarding the past of the Islands, but one single fact may serve as a demonstration of what has been said above regarding the lack of an adequate national organization in control of the archeological survey.

Until about 1924 all that was known concerning a possible Stone Age civilization in the Philippines could easily be contained in a few pages, as only a few stone implements had then been uncovered. However, since that date, thousands of stone implements are said to have been discovered, chiefly in Rizal Province in central Luzon. Unfortunately, only little has been published about these discoveries. It is possible that a methodically conducted survey as to the classification of the stone implements, their chronology and geographical distribution, would reveal data regarding the various phases of the earliest settlements and related facts. A comparative study of the relics may also give some valuable information on the earliest trade and cultural connections with neighboring countries, as well as on invasions and internal ethnic movements. It may be of interest in this connection to recall the fact that until Dr. J. G. Anderson, the founder of the Museum of Far Eastern Antiquities in Stockholm, made his star-

tlings discoveries in Honan and Kansu about 1920, most scholars were inclined to deny the existence of a Stone Age civilization in China.

How the Philippines first learned the use of metals—a step of capital importance for the promotion of the material advancement of any civilization—is still another problem clothed in mystery. It has been assumed that the Dong-son civilization—spread over large areas in southwestern China and southeast Asia—reached the Philippines from the region of the Gulf of Tonkin at the beginning of the Christian Era. The Dong-sonians were well acquainted with the utilization of metals, especially bronze and iron. Consequently it would be tempting to connect the introduction of the knowledge of metals and their use in the Philippines to the Chinese-inspired Dong-son civilization. As tangible evidences of this civilization had been found in many places in Indochina and as far south as the East Indies, it is not unreasonable to anticipate the possibility of the discovery in the Philippines of items characteristic of the “Dong-sonian.” However, there are no facts yet known which could substantiate the theory linking the Dong-son civilization to the introduction of metallurgy in the Philippines.

It can be taken for granted that China and India were the main sources of cultural impact prior to the Spanish intervention. The time or period when these influences first made themselves felt and the extent to which they affected the daily life of the inhabitants, spiritually or materially, are still open questions. It is known, however, that there were trade relations with Siam in the fourteenth and fifteenth centuries and that these relations may have brought to the Philippines both Chinese and Indian cultural elements. Though Chinese chronicles mention Philippine relations with China during the Sung dynasty (960–1126), it is possible that China exercised some influence in the Islands prior to this period. Another problem concerns the effect of Arabic and Muslim influences, especially in the southern islands. Only the spade of the archeologist, however, can provide the answers to these questions.

These are only a few of the problems which archeologists will have to face in the future. If adequately supported and guided, young Filipino scientists will find here in years to come a vast and fruitful field of research.

RECENT DISCOVERIES OF EARLY MING WARES IN THE PHILIPPINES

It is not within the scope of this paper to deal with all these questions. Instead, a single problem has been selected as a sample for a more detailed study, namely, Chinese influence during the early Ming dynasty (1368–1644) as seen in the light of recent discoveries.

During this period Chinese ceramic art and handicraft reached one of its highest peaks. However, until recently our knowledge of the

wares of the early part of this period has been rather defective, because, as a rule, they have not been found in tombs—the main source of our knowledge of ancient ceramics—either in China or Indochina. As a matter of fact, it was prohibited at that time in countries ruled by the Chinese Emperor to use ceramics as funerary deposits. However, in the Philippines, free of Chinese rule, the inhabitants frequently deposited in the tombs of their departed ones Chinese ceramics, introduced to the Islands by trade. Even though the wares exported were not always of the highest quality, they nevertheless are of great documentary value. With the aim of filling some gaps in our knowledge of early Ming ceramics and their use for funerary purposes in the Philippines, the writer during several months in 1940 made systematic excavations in various parts of the Philippines. Of greatest interest was the discovery of three cemeteries on the Hacienda of Calatagan in the Province of Batangas, in central Luzon. As the material uncovered by these excavations may provide some basis for further archeological field work, a short description will be given of the collections and the circumstances under which they were made.

EARLY MING WARES FOUND AT CALATAGAN

The estate of Calatagan is situated about 150 miles south of Manila opposite Lubang Island. A few years ago when the ground was being leveled for an airfield, near a natural mound called Penagpatayan, some Chinese potsherdts were found and given by the owners of the estate, Enrico and Jacobo Zobel, to the Manila Museum. When the writer's attention was drawn to these findings, it occurred to him that systematically conducted excavations in this locality might lead to the discovery of interesting specimens of early Ming ceramics and possibly give some information regarding burial customs of the local population at that time, and at the beginning of 1940 arrangements were made with the owners of the estate for such excavations. We not only located a cemetery on the very Penagpatayan mound, but also two others nearby, comprising altogether about 70 tombs, chiefly from the time of the early Ming dynasty, and yielding hundreds of specimens of Chinese and native ceramics, as well as other items.

The three cemeteries are all situated close to the shore:

1. Penagpatayan, a few kilometers west of the Calatagan clubhouse, and between the projected airfield and a fish pond. To the north are seen the Wolang Boahibo, Cato, Itim, and San Pedrino Mountains. The tombs are located on a natural mound with gently sloping sides, which have been under cultivation for many years.

2. The Pulong Bacao (Bakaw) field is located on a flat promontory about 1 kilometer northwest from Penagpatayan. A part of the ground had been cultivated for some time, but was now abandoned

and largely overgrown with shrubby vegetation. According to the manager of the Calatagan estate, several "old Chinese potsherds" had occasionally been turned up here by the plow, and a local worker is said to have found a ceramic box containing some Spanish silver coins.

3. The Kay (or Panday) Tomas field, also on a flat promontory, is surrounded by swamps. The field is located a few kilometers north of the Pulong Bacao field. At Penagpatayan we discovered 29, at Pulong Bacao 6, and at Kay Tomas 31 tombs, a total of 66 tombs, most of them from the early Ming (fifteenth and sixteenth centuries). In the soil between the tombs and almost on the surface we gathered, in addition to the various items of the funerary deposits, numerous stray finds.

As a rule each tomb contained a skeleton or part of a skeleton, lying on its back, the arms generally inclined slightly inward. At Penagpatayan the limestone ground was partly responsible for the good preservation of the skeletal remains. At the other cemeteries, especially at Pulong Bacao, the bones were in many cases in a poor state of preservation. The various pieces of the funerary deposit, chiefly Chinese ceramics, has been placed on or around the skeleton. In addition to ceramics, there were other items, such as spindlewhorls, a pounder, a bracelet, and a knife. There were no traces of a coffin or an underground chamber of bricks, stone, or other material. Originally, however, there may have existed above the tombs some structures of wood, which, of course, have not been preserved. Such constructions still are erected in various parts of southeast Asia above modern tombs, e. g., among the Protomalayan populations, and are common among the Moros in the south. The skeletons and the funerary deposits were uncovered usually only a few feet below the surface of the soil.

A peculiarity of the Penagpatayan field was the disposition of the tombs along a slightly curved line, extending in a north-south direction. With the exception of two tombs (9 and 10) all were found oriented in or almost in a north-south direction, with the skull to the north.

The regularity with which the graves have been arranged may indicate that the dead had been buried approximately at the same time. The name of the mound, Penagpatayan, meaning the Field of Massacre, could possibly substantiate this theory. Some of the dead appear to have met a violent death, because in several cases the skeletons showed evidence that the dead had been mutilated. The fact that several skulls were missing seems to indicate that some of the dead had been victims of head hunters.

Before describing the various types of ceramics excavated, a brief discussion of local funerary rites as revealed by our discoveries may

be of interest. As previously mentioned, the dead had generally been buried on their backs in outstretched position. There were only a few exceptions. In some cases, especially at Penagpatayan, the individuals appear to have been mutilated, as parts of the skeleton were missing (part of the thorax, an arm, or the skull). In one case (Kay Tomas tomb No. 26) we found two skulls at the feet of the dead. In tomb No. 21, Kay Tomas, the skull was placed in a bowl. The writer once noted a similar burial custom in a Han tomb discovered at Lachtruong, Thanh-hoa Province, in northern Annam. Occasionally we found only the skull, together with funerary deposits. Near the central part of one skeleton (Kay Tomas No. 29) we found the remains of two other small skeletons, possibly a mother and her two children. One skeleton had teeth that showed traces of a black varnish (possibly due to betel chewing) and were provided with gold plugs. The custom of inserting gold plugs in the teeth is said still to occur among the inhabitants of Visayan Island. In tomb No. 15 Kay Tomas, we found alongside the skeleton a layer of shells which is of interest because shells play an important role in many lands with regard to fecundity and burial customs. In northern Annam in 1937, the writer found shells in one of the more stately tombs from the Han dynasty. Examples of tombs with their funerary deposits are shown in plate 1.

The osteological material was studied on the spot by Dr. Gerardo Manas, physician of the Calatagan estate. Owing to the outbreak of the war, the report Dr. Manas then prepared never reached us. However, according to an oral report to the author in 1940, the measurements gave indices characteristic of modern Filipinos in Luzon. On the basis of this information it appears safe to assume that most of those buried were natives.

As already pointed out, the deposits generally comprise various types of ceramics, found at the head, the feet, or above the legs or the middle region. We noticed that the ceramics, especially those placed above or close to the middle region, had often been deposited in inverted position. This disposition is undoubtedly intentional and may have significance, possibly connected with fecundity rites. It is noteworthy that in Annamite tombs from the Sung dynasty (960-1126) discovered in Thanh-hoa Province, northern Annam, the writer also found a similar disposition (though there were no actual skeleton remains left owing to the destructive influence of the soil).

Most of the ceramics we discovered at Calatagan are of Chinese make, but by what routes did the ceramics reach the Philippines? Some of the wares were apparently imported direct from Siam, where the Chinese had established the famous Sawankhalok kilns in 1350. Other wares may have reached the Philippines from China either directly or by way of Annam or Tonkin or the East Indies, where the Chinese

had established close trade relations prior to the Ming period (1368-1644). It may be mentioned that the Chinese, according to B. Laufer, had established in pre-Spanish times a settlement in Mindoro (opposite the Calatagan cemetery). The same author also surmises that the Chinese had established themselves on Mindoro before they came over to Luzon. It is possible that this colony had trade relations with kinsmen on the continent and that some of the ceramics found at Calatagan were introduced by these settlers on Mindoro. It would be of interest to have scientifically controlled excavations carried out on this island, which might throw some light on early trade relations between China and the Philippines.

The Chinese ceramics which we found present many varieties, but there are a few standard types, such as earthenware, glazed jarlets or bottles (possibly perfume containers), bowls, saucers, and dishes of glazed porcelain, most of them decorated in blue and white, occasionally in green with cream-colored glaze. There are also monochrome wares in white, celadon, light green, and brown. A few specimens in white, red, and green are from the Wan-li period (1573-1620). Plate 13, upper left, and plate 14 present the most typical specimens. Some of the most characteristic examples will be described below.

1. *Jarlets*.—They appear in three principal types: (a) Globular body and narrow, low neck. The jarlet is provided with a milk-white crackled glaze. There is no special decoration. (b) Almost cylindrical body with a comparatively wider neck. White shiny glaze and bluish decoration. (c) Pear-shaped body with rather wide but low neck; small handles on the shoulders. The glaze is usually grayish or brownish. The pear-shaped jarlets are believed by some writers to have been imported from Siam, probably in the fourteenth century.

2. *Bowls* are rather common. Some of them are monochrome, with white, greenish, or less often brownish, glaze. Often the monochrome wares are without special decoration, but some show underglazed grooves, intended possibly to outline a conventionalized lotus pattern. One of the most spectacular types is thin-walled, blue and white, generally embellished with rows of elongated leaves, possibly intended to reproduce artemesia leaves, which play an important part in Chinese art and folklore as a symbolic motif. The bottom, inside, shows either a more or less conventionalized shell, lotus, or a character. The shell and the lotus are common motifs and were used partly because of their symbolic value.

3. *Saucers*.—One of the more peculiar types of this category is the so-called hole-bottom saucer. A marked feature of this type of saucer is that instead of the usual ring-shaped ridge around the bottom, there is a cylindrical depression, often surrounded by an unglazed yellowish

zone. The saucers show a shiny white glaze, usually with a goldfish pattern in overglazed red-enameled slip in the center. The eye is white with a black pupil. Inside along the rim are decorations in blue, reminiscent of seaweed. Occasionally there is instead of the fish motif a combination of the character for luck, and the god of happiness. It is not clear why on these wares the customary bottom ridge is replaced by a depression, apparently an innovation made during the early Ming. One possible explanation is that the saucers were intended to be placed on a cylindrical stem which would fit the hole. The stem may have been made of wood or some other perishable material, which would not have lasted until modern times. It should be recalled in this connection that there existed in Ming times a ware comprising a saucer-shaped upper part on a porcelain stem. The hole-bottom saucers, four of which have been found at Penagpatayan, have been assigned by some writers to the fifteenth century.

4. *Dishes* provided with a cylindrical ridge at the bottom appear in various colors. They are generally white-glazed, embellished with designs in blue. Occasionally the glaze is cream-colored and the design greenish. Monochrome celadon dishes are rare. The rim is either straight or slightly waved. Occasionally the bottom, even inside the circular ridge, is glazed. The dishes are among the most spectacular of the ceramics and show a variety of designs. One of the most common patterns is the ch'i-lin, a fantastic composite animal with the head of a dragon, body of a deer, slender legs, divided hoofs, and bushy tail, some of the last-named reminiscent of a lion's tail. This extraordinary animal appears among curling flames, a manifestation of the divine nature of the ch'i-lin. This most noble creature in Chinese mythology is believed to appear as an omen of a good ruler to come and that it attains the age of 1,000 years or even more. Another common motif is composed of four flowers (chrysanthemums) combined with some other floral designs. In a few cases the dishes present a fish design in blue, surrounded by seaweed; these dishes are said to be of an "early fifteenth-century type." Rather common is the design of a flower (chrysanthemum?) in a vase. We found only one such dish at Penagpatayan, but several at Kay Tomas. A few specimens show an interesting picture of a man and a woman in blue, which motif may be interpreted as the spinning maiden and her lover, the cowherd, meeting in the skies, a well-known motif in Chinese folklore. In addition to the above types, we found, as already mentioned, several native red-ware vases and dishes. The chronology of these wares is uncertain, but as they occur in tombs which can be ascribed to early Ming, it is evident that they were already being produced at that time, but it is possible that the same wares were also made later.

CHRONOLOGY OF THE TOMBS

As but few systematically conducted excavations have been carried out in the Philippines and relatively little has been published in this field, we do not yet possess a solid basis on which to build up an absolute chronology in respect to the above finds. It appears, however, (Robb, *op. cit.*, *passim*), that Ottley Beyer (Manila) has excavated "certain stratified deposits" in Rizal Province, central Luzon, containing "quantities of fragments and whole pieces of Oriental stoneware and porcelains, mainly of Chinese and Siamese origin." An attempt has been made by one writer to assign various types of ceramics to a certain date, based on information given by Mr. Beyer. Unfortunately, however, none of the "horizons" or archeological strata with their contacts and interrelations have been published to substantiate the proposed chronology. Pending an adequate report and possible further excavations, the question concerning the date of the tombs from Calatagan remains open. It is possible that the Penagpatayan cemetery is older than those at Pulong Bacao and Kay Tomas. As the latter has produced a few specimens belonging to the Wan-li period (1573-1620), it is obvious that although some of the burials were made at the end of the sixteenth century, most of the tombs may belong to the middle or early sixteenth century. At Penagpatayan no Wan-li wares were found, and though some of the ceramics are of the same types as those found at Kay Tomas, most of the wares appear, on the basis of the chronology suggested by Beyer, to be of older types. It is therefore possible that the Penagpatayan findings should be regarded as belonging mainly to the fifteenth century.

The Pulong Bacao findings show a number of similarities to those made at Kay Tomas. It is therefore safe to assume that these two cemeteries may be regarded as practically contemporaneous.

SURFACE FINDINGS

In addition to the various items of the funerary deposits, we discovered numerous objects in the soil between the tombs and near the surface, especially at Pulong Bacao and Kay Tomas. Most of the findings are potsherds, many of which are interesting because of their decoration, some simple beads, a few ceramic spindlewhorls, some bracelets of green and blue matter (possibly glass paste), and several stone implements. Though a few of these items may originally have belonged to funerary deposits (which might easily have been displaced), it is obvious that some of the findings indicate that there once existed a settlement very close to the cemetery, a feature which is still common in the southern islands and occurs elsewhere among Protomalayan peoples as, for example, the Moi in Annam.

Some of these surface findings of potsherds and stone implements are of sufficient interest to be described here. At Pulong Bacao and Kay Tomas we found that several bowl bottoms had been intentionally chipped along their edges to be used as throwing pieces, a common plaything for children in many parts of the world.

Some potsherds belong to big pear-shaped jars of the type described in articles on pottery findings in the Philippines, showing dragons in high relief and other motifs done with incised lines. On the shoulders are handles in the shape of the Dog Foo, presenting on the forehead the character for Orient. The jars are of stoneware with greenish glaze. At Pulong Bacao we found parts of several such vessels. Originally they may have been deposited in the earth as an offering to the spirits, or they may have been temporarily buried to preserve fermented beverages, a custom still practiced among the Moi tribes in Annam.

Such jars have been exported from China to many places in south-east Asia where the local population still regards them as animated or as possessing supernatural powers. When such jars are found by the natives in the Philippines, they are often intentionally crushed ("killed") to prevent treasures supposed to be hidden in the vessel from disappearing mysteriously.

A big jar found a few years ago by Fr. Worcester at Bohalebung near Lamitan (Basilan Island) contained several smaller vessels and some Chinese coins from the fifteenth century.

STONE IMPLEMENTS

Most of the stone implements are axes or ax-shaped objects, many reshaped for polishing, grinding, or some other secondary purpose. Plate 15 gives an idea of the various types represented in our findings from Calatagan. One ax had been transformed into a scraper; another had its edge flattened as if it had been used for pounding or grinding. Part of another ax (square cross section and beveled edge) also had its edge flattened as if it had been used in the same way. The stone ax in many parts of the world is still looked upon as a magic object, as a charm or a thunderbolt, and is thought to be possessed of protective or curative powers. The sorcerers of some mountain tribes in Annam rub the edge of a stone or bronze ax against the bottom of a bowl, an action which is believed to give healing power to the liquid subsequently poured into the vessel. It is possible that the inhabitants of the Philippines, before they were converted to Christianity, practiced similar customs.

Several disk-shaped pounders were used, in the opinion of our workers, as mortars in which betel nuts were pounded with pestles. According to some unconfirmed reports, similar disks have been thus

used in recent times, but this may well be a secondary use. This type of implement is also represented in Indochina, and has been found, for example, in the old dwelling place at Bao-Tro near Dong-hoi in Annam.

In addition to axes, axlike implements, pounders, pestles, and grinding stones, we found what may be a part of a knife, a few obsidian flakes, a netsinker, and a phallus-shaped object.

The occurrence among the surface findings, especially at Kay Tomas, of several stone implements, seems to indicate, as mentioned, that there may have existed in the vicinity a Stone Age dwelling site. As primitive man in many parts of the world used stilt dwellings erected on the shore in sheltered creeks or on the river banks, it is possible that further research made along the shore may reveal the existence of such dwelling places, and also give some information regarding possible upward or downward movements of the land with consequent displacement of the shore line. Such stilt dwellings are often seen even today in large areas of southeast Asia.

CONCLUSION

In this paper we have discussed briefly an attempt to throw some light on a single facet of Philippine prehistory, and have suggested some of the unsolved problems awaiting archeologists in that interesting region. As already mentioned, one of the most effective means of furthering archeological research in the Philippines would certainly be the creation of a national board of archeological survey as once conceived by the late President Manuel Quezon. Such a board would be in a position to promote our knowledge of the Filipino peoples in pre-Spanish times, first, by directing and sponsoring scientifically conducted excavations and research, and second, by recommending appropriate legislation prohibiting uncontrolled digging in ancient graves and dwelling sites, which generally are of little, if any, benefit to archeological science. May it also be suggested that adequate reports on excavations already carried out should be published, as well as descriptions of existing public and private collections of antiquities found in Philippine soil.

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EXPLANATION OF PLATES

PLATE 1

LEFT: Penagpatayan (Calatagan), Luzon. Tomb No. 19. Skeleton, on the back, extending north-south, the feet to the south. The skull is missing, being replaced by a dark-green glazed bowl, slightly damaged, adorned outside with a conventionalized lotus pattern. At the feet are placed two light-green glazed bowls with no decoration. Height, 6.2 cm. and 6.6 cm. All three bowls were found in inverted position. (Photograph by O. Janse.)

CENTER: Penagpatayan (Calatagan), Luzon. Tomb No. 18. Skeleton, on the back, extending north-south, the skull to the south. Behind the skull an eared, pear-shaped earthenware bottle with the neck missing. Height, 9.7 cm. Over the middle region was placed in inverted position a "hole-bottom" dish, diameter, 12.5 cm. Immediately above the knees was a blue and white porcelain dish with waved edge and bottom ridge. In the center are seen a *ch'i-lin* and different symbolic signs (fire, clouds, etc.). At the back of the *ch'i-lin* is a sand spot due to bad baking of the ware. Along the edges are geometric patterns. Outside, between the bottom ridge and the edge, are dots and curved lines (conventionalized flowers or leaves). Diameter, 17.7 cm. At the right foot was a badly damaged globular earthenware red vase.

RIGHT: Kay Tomas (Calatagan), Luzon. Tomb No. 31. Skeleton in very bad state of preservation, on the back, extending north-south, the skull to the south. At the right arm was placed vertically a blue and cream-colored saucer decorated inside and outside with conventionalized flower patterns. Diameter, 18.2 cm. Over the middle region were placed in inverted position three bowls, two of them broken, white and light blue, decorated along the mouth (outside) with a row of leaves; inside no decoration. Height, 4.8 cm. and 5.2 cm. The third bowl, blue and white, is entirely glazed, even the base and the foot ring. Outside, along the mouth, one horizontal blue line; another around the foot ring. Inside, some blue horizontal lines. Height, 5.4 cm. Above the knees was found a blue and white dish decorated with a "flower in a vase." Above the feet was found, in vertical position, a cream-colored bowl with foot ring and a blue-greenish decoration. Inside, in the center, surrounded by a circle, a conventionalized lotus. Outside, along the mouth, groups of oblique lines and few curved ones. Height, 5.2 cm. About half a meter from the right knee was found a native red-ware vase with elongated, vertical impressions. Height, 11 cm.

PLATE 2

UPPER: Test trenches being dug at Mulasvin (Ilat), Dalipit, Luzon, where a bronze ax of Dong-son type is said to have been found. In the foreground, back to the camera, is Mr. Sison of the National Library, Manila, who was asked by the Secretary of National Education to accompany the author and serve as an interpreter. To the right of Mr. Sison is the local constabulario. (Photograph by O. Janse.)

LOWER: Skeletons from tombs 1 and 2, Penagpatayan (Calatagan), Luzon, after the funerary deposit had been cleared. The two skeletons, on the back, extending north-south, looking in opposite directions. The limestone ground on both sides of the skeletons is visible in the picture. The tombs contained numerous ceramics.

PLATE 3

LEFT: Part of a skeleton with the skull facing northeast, placed in a bowl. Some skeletal remains, placed close to the skull, give the impression of having been compressed in a container which has not been preserved. The bowl is glazed, adorned outside with misty waved lines. Diameter, 13.5 cm. Kay Tomas (Calatagan), Luzon.

Close to the bowl was found a large, well-preserved blue and cream-colored porcelain dish with a flower design. On the outside four wheel-shaped flowers with their branches. The dish was in inverted position. Diameter, 26.5 cm. Near the dish was placed a native globular red-ware vase. Height, 14.5 cm.

RIGHT: Penagpatayan (Calatagan), Luzon. Tomb No. 4. Human bones and a small skull, probably that of a child. Over the bones of the thorax was an inverted bowl, and around the bowl fragments of a large native vase of red ware originally inverted to cover the bowl, which was green glazed and undecorated, measuring about 12 cm. in diameter.

PLATE 4

- LEFT:** Blue and white glazed dish with a *ch'i-lin* and various symbolic and geometrical patterns. Penagpatayan (Calatagan), Luzon.
- CENTER, UPPER:** Bowl with foot ring, cream-colored glaze and blue decoration. Inside at the bottom the character *fu*, the same component that is used to indicate Fu Shen, the god of happiness. Outside the rim is a zone with oblique lines. Around the footing a leaf pattern, possibly conventionalized artemesia leaves. Height, 5.5 cm.
- CENTER, LOWER:** Part of a blue and white dish with foot ring as seen from below. Inside at the bottom five flowers, leaves and branches inside parallel lines. On the sides, both inside and out, a similar pattern. The space inside the foot ring is glazed. Diameter, 19 cm. Penagpatayan (Calatagan), Luzon. Tomb No. 5.
- RIGHT:** Light-greenish porcelain dish with foot ring. Dark-greenish decoration. Inside, a chrysanthemum in a vase. Outside, no decoration. Diameter, 19 cm. Incidental find. Kay Tomas (Calatagan), Luzon.

PLATE 5

- UPPER:** Glazed blue and white bowl with foot ring, decorated at the bottom inside with shell pattern; outside, a row of artemesia leaves. Height, 6 cm. Kay Thomas (Calatagan), Luzon. Surface find.
- LOWER:** "Hole-bottom" saucer decorated with a fish and seaweed patterns. Penagpatayan (Calatagan), Luzon. Tomb No. 7.

PLATE 6

- UPPER:** Glazed blue and white pear-shaped jarlet with conventionalized flower or leaf patterns. Height, about 5 cm. Kay Tomas (Calatagan), Luzon.
- CENTER:** Glazed yellowish bowl with foot ring and provided outside with an incised conventionalized lotus pattern. Height, 6 cm. Penagpatayan (Calatagan), Luzon.
- LOWER:** Glazed light-greenish bowl with low foot ring and slightly out-bent mouth. The glaze is crackled. The foot ring is unglazed. Height, 5.6 cm. Kay Tomas (Calatagan), Luzon. Tomb No. 11.

PLATE 7

- LEFT:** Pear-shaped bottle of brownish, glazed earthenware, originally provided with two small handles on the shoulders. The neck is low and somewhat curved. The bottom is unglazed, reddish. Height, 10.5 cm. Penagpatayan (Calatagan), Luzon. Tomb No. 3.
- CENTER:** Light-green glazed bottle with the foot ring and two small handles. On the shoulders and on the body several dark lines running in various directions. The lower part of the body is red, unglazed. Height, 10.5 cm. Kay Tomas. Incidental find. Possibly Savankhalok ware. Coll. Zobel.
- RIGHT:** Almost pear-shaped earthenware bottle with originally milk-white glaze covering the body except at the bottom. The glaze has partly deteriorated. At the bottom is a foot ring. The neck is missing. On the shoulders, traces of two small handles. Found near the skull of the skeleton in tomb No. 1, Penagpatayan (Calatagan), Luzon. Height, 12.1 cm.

PLATE 8

- UPPER: Double-edged iron knife with tenant. Length, 14.4 cm. Penagpatayan (Calatagan), Luzon. Tomb No. 14.
- CENTER, LEFT: Bracelet with square cross section of light-bluish matter. Diameter, 7.3 cm. Kay Thomas (Calatagan), Luzon. Surface find. A similar bracelet was found in tomb No. 26 at Kay Tomas.
- CENTER, RIGHT: Bracelet of light-green matter (glass or glass paste?) with almost triangular cross section. Diameter, 6.3 cm. Kay Tomas (Calatagan), Luzon. Tomb No. 12. Another similar bracelet was found in the same tomb.
- LOWER, LEFT: Almost cylindrical handle (?) of bone, slightly narrowing toward one end. At the wider end are two parallel swellings and at the narrower end one such swelling. The surface is polished. Length, 3.6 cm. Pulong Bacao (Calatagan), Luzon. Tomb No. 2.
- LOWER, RIGHT: Part of a handle made of a hollowed deer antler (?). Pulong Bacao (Calatagan), Luzon. Surface find.

PLATE 9

Chinese characters on potsherds belonging to the bottom of various ceramics.

- UPPER, LEFT: Character *fu*, happiness. Kay Tomas (Calatagan), Luzon. Tomb No. 15.
- UPPER, RIGHT: Character *fu*, happiness. Kay Tomas (Calatagan), Luzon. Surface find.
- CENTER: Character *cha*, tea. Kay Tomas (Calatagan), Luzon. Tomb No. 18.
- LOWER, LEFT: Character meaning long life. Penagpatayan (Calatagan), Luzon. Surface find. The man in the character may be Shon Hsing, the god of longevity.
- LOWER, RIGHT: Character meaning white (purity?). Kay Tomas (Calatagan), Luzon. Surface find.

PLATE 10

- LEFT: Potsherd (glazed, blue and whitish), showing more or less conventionalized lotus pattern on the bottom, inside. Surface find from Kay Tomas (Calatagan), Luzon.
- RIGHT: Potsherd (glazed blue and whitish), showing more or less conventionalized lotus pattern. Surface find from Kay Tomas (Calatagan), Luzon.

PLATE 11

- LEFT: Part of a large dish (rim and interior). Surface find at Kay Tomas (Calatagan), Luzon.
- CENTER: Part of a dish, blue and white. Bohelbung, Basilan Island.
- RIGHT: Part of a jar, white glazed with brownish flower design (incised outlines). Surface find from Kay Tomas (Calatagan), Luzon.

PLATE 12

- LEFT: Part of a glazed blue and white ceramic, showing a rinceau pattern. Penagpatayan (Calatagan), Luzon. Surface find.
- RIGHT: Part of saucer, glazed blue and white, showing the interior (bottom) with fish design. Kay Tomas (Calatagan), Luzon. Surface find. The design appears to represent an intermediate stage between the enameled goldfish of the hole-bottom saucer type and the blue design seen on some small glazed dishes.

PLATE 13

- UPPER, LEFT: Part of a cover from the Wan-li period (1573-1620) found at the same place where previously two stone statues are said to have been found, Palambang (Calatagan), Luzon. The cover is glazed, decorated with geometrical and conventionalized flower designs in red and green.
- UPPER, RIGHT: Jar of grayish ware with a bronze gong used as lid, found by Fr. Worcester at Bohelbung, Lamitan, Basilan Island. The jar contained numerous beads of glass, three small bronze rattles, ceramic bowls and dishes (blue and white), and Chinese coins from the fifteenth century.
- LOWER: Blue and white ceramics (large dish and bowl) said to have been found near Lamitan, Basilan Island. Private collection.

PLATE 14

- White glazed potsherds with red and green decoration (conventionalized flowers and geometrical patterns) from the Wan-li period (1573-1620). Upper and center found in tomb No. 15, Kay Tomas (Calatagan), Luzon.

PLATE 15

- Stone implements found at Kay Tomas. All the objects are surface finds.
- UPPER: End of a flat knife or sickle originally possibly in shape of a section of a disk. One face shows numerous strokes in all directions, which indicate that the fragment was used as an anvil. Sandstone.
- CENTER: Almost oval grinder of light-green stone, one face flattened by grinding.
- LOWER, LEFT: AX of dark stone with dark-greenish surface. The edge has been partly broken in recent times.
- LOWER, RIGHT: Lower part of a pestle with elliptic section. Sandstone.



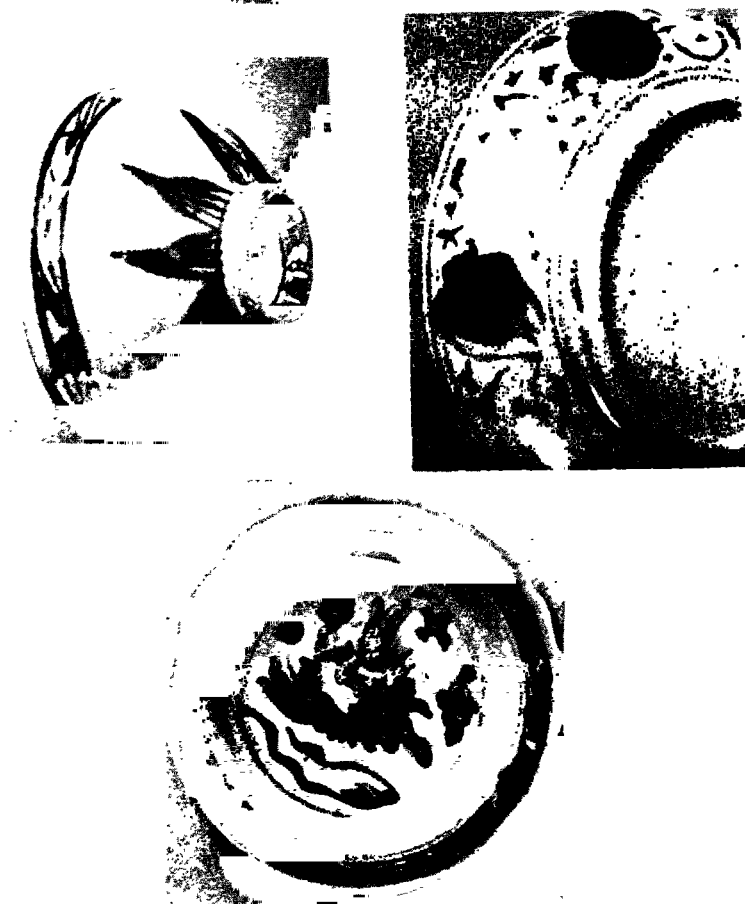
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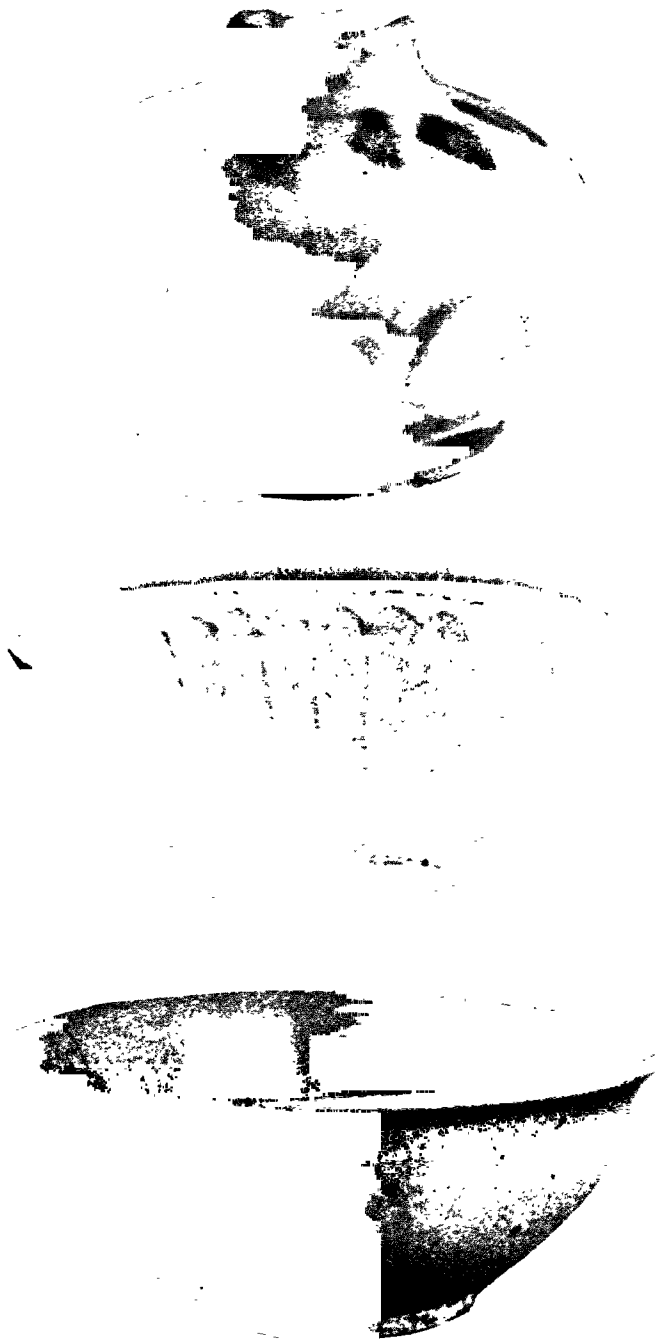
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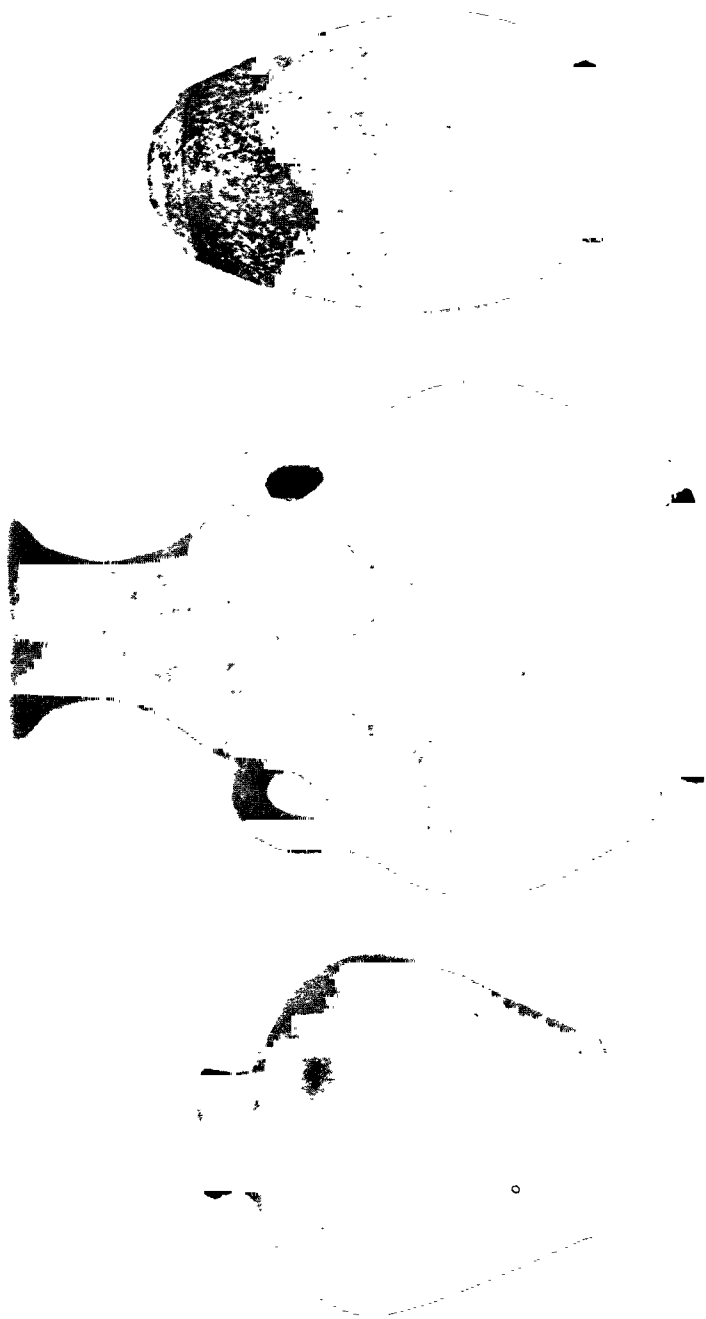
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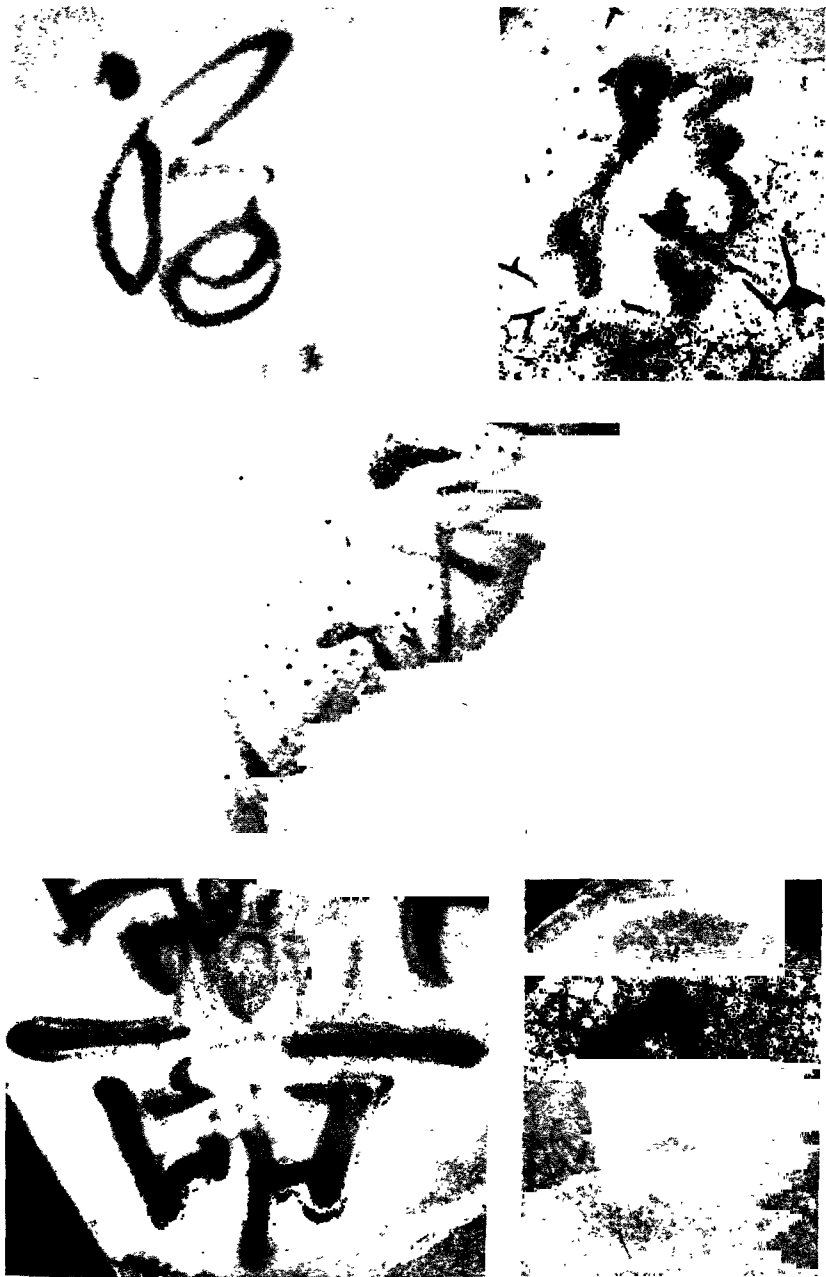
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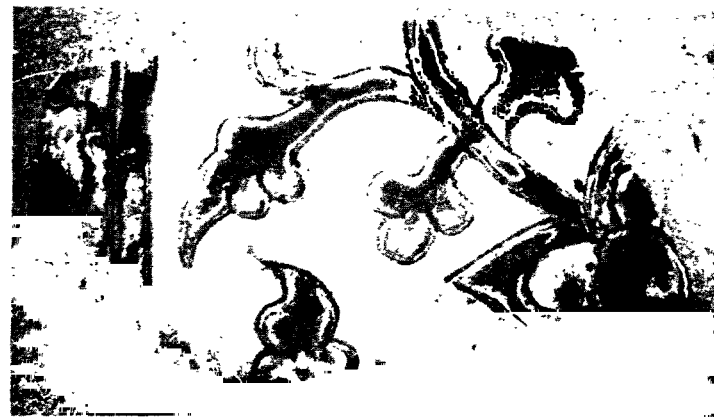
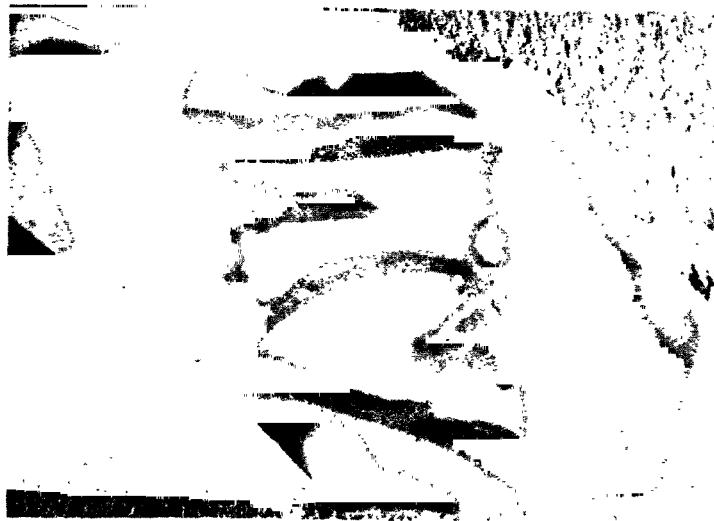
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PALESTINIAN POTTERY IN BIBLE TIMES¹

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[With 3 plates]

We live in a day of synthetics—synthetic rubber, synthetic gasoline, synthetic perfumes, and countless others. The first synthetic to be discovered by mankind was pottery, an artificial stone produced by firing clay shapes to a temperature sufficiently high to change the physical and chemical properties of the original clay into a new substance with many of the characteristics of stone. Some of the earliest known pottery in the world comes from Palestine, where it was known and used as early as 5000 B. C. A study of this pottery proves that the early Palestinian potters made striking progress in mastering the numerous technical problems involved in the various types of clays, in fashioning techniques, in decorative styles, and in firing methods.

It is the stonelike property of pottery which makes it so invaluable to the archeologist for, even if a jar is broken into pieces, the fragments are imperishable. The fires which destroyed so many ancient cities did not affect them; the rains of the centuries and the chemicals in the soil did not change them. Glue the broken pieces together and you have the very vessel itself which the ancients used! This imperishable nature of pottery makes it the most common find in any excavation, and it usually outranks in quantity all other finds put together.

The ancient world was style-conscious about its pottery, and thus new shapes were constantly replacing old ones just as they do today in modern tableware. It is by a patient, painstaking study of these ancient pottery styles that the archeologist has learned at what date a new style arrived and at what date it went off the market. Some styles were rather persistent in long life cycles, but others changed more rapidly. It is these latter which furnish the archeologist his most important calendar for ancient Palestine.

¹ Reprinted by permission from *The Biblical Archaeologist*, vol. 8, No. 4, December 1945.

Historical dates carved in stone or written with ink on papyrus are, of course, the ideal calendar data, but they are seldom preserved for the archeologist in Palestine. The fires of the conquerors which destroyed the cities not only burned up the papyrus records, but also quickly calcined any limestone inscriptions. Even if they escaped the fires, the rains of the centuries have almost always destroyed both. Thus the archeologist is forced to do most of his dating in Palestine from pottery. The accuracy of this method, however, is assured, for south-west of Palestine lies Egypt, from which objects were imported and in which pottery from Palestine is found. In Egypt these objects are dated by a wealth of inscriptional data. In fact, it was Sir William Flinders Petrie, the Egyptologist, who first discovered the importance of dating by means of pottery when he worked in Palestine in 1890. It was not until about 15 years ago, however, that the complete calendar for Palestinian ceramics was worked out.

PALESTINE'S ARCHEOLOGICAL PERIODS

The major periods of Palestinian history in terms of pottery chronology are as follows:

Neolithic Age—c. 6000–4500 B. C. It was toward the close of this period that pottery first appears, c. 5000 B. C.

Chalcolithic Age—c. 4500–3000 B. C. This was the great period of irrigation culture in Palestine and the time that copper was introduced into use there.

Early Bronze Age—c. 3000–2000 B. C. These years saw Egyptian Dynastic history begin and Egypt exert a strong cultural influence on Palestine.

Middle Bronze Age—c. 2000–1500 B. C. Palestine was under Egyptian political domination when this period opened and remained so through the days of Abraham \pm 1900 B. C. The Hyksos, however, captured Palestine and Egypt in the days of Joseph and controlled both lands until Egypt sprang back as a world power about the end of this period.

Late Bronze Age—c. 1500–1200 B. C. This marked the close of Israel's sojourn in Egypt, the Exodus, and Joshua's conquest of Palestine.

Iron Age I—c. 1200–1000 B. C. The period of the Judges to the time of David, during which iron came into common use.

Iron Age II—c. 1000–587 B. C. From David to the destruction of Jerusalem.

Iron Age III—587–333 B. C. Exilic and post-exilic period; predominantly Persian period.

Hellenistic Period—333–63 B. C. Alexander the Great, to Roman conquest of Palestine.

Roman Period—63 B. C.—A. D. 325. New Testament and early church.

Each of these major periods is, of course, broken up into various minor ones depending upon numerous details in the changes in style and in types of ware within a major period. Using pottery alone for calendar purposes, the date of any city of Bible times can be worked out to within about 50 years of its life date. Sometimes the sudden appearance of a foreign pottery gives an exact date, as when the Philistines invaded Palestine and brought along a brand new type of pottery. The perfect example of date is illustrated by an inscription on a bowl found in Lachish which may enable us to date the conquest of that city by Joshua about 1230 B. C. The most striking piece of historical research using the pottery calendar has been done by Dr. Nelson Glueck, Director of the American School in Jerusalem. He has visited virtually every ancient site in Transjordan south of the Yarmuk River, and by a careful study of the pottery found on each site, he has been able to work out in broad outlines the history of Transjordan from prehistoric times.

Until Abraham's time most Palestinian pottery was hand-made. This type of pottery can be recognized quickly for it lacks the perfect symmetry of ware thrown on the potter's wheel. Some hand-made pottery is of eggshell thinness, but in general it is heavier than thrown ware. In one common type of hand-made ware the vessel was built up of coils of wet clay. Then with the fingers of one hand pressing against the inside of the jar and the fingers of the other hand working against the outside, the clay was modeled into the desired shape. Another type was made by molding the clay over some desired shape such as a basket or a broken jar. Other techniques also were used, and with all of them there might be a final truing-up process while the jar was turned round and round upon a mat. If the vessel was a large one, it was built up on the installment plan, allowing the lower sections to dry somewhat before new ones were added, lest the weight of too much wet clay cause the walls to collapse. American Indian pottery is a good example of hand-made ware. The true potter's wheel was never discovered by the early American Indians.

A few of the most characteristic features of Palestinian pottery before Abraham's time are: flat bottoms, wide mouths, inverted rims, and spouts. Handles were of the small pierced-lug type for hanging ware, the heavy ledge type for lifting large vessels, and the graceful high-looped handle for tableware. The most common decoration was burnishing (see below), which to the inexperienced looks like a polish and is often incorrectly called so. In painted ware the most common decoration was a drip or net design.

The invention of the true fast-spinning potter's wheel revolutionized

the whole pottery industry, not only speeding up production phenomenally but also improving structural design and esthetic qualities. The older flat-bottomed jars were replaced by round-bottomed ones which did not break so easily. Narrow mouths were now made as easily as wide ones. Spouts largely disappeared because a thrown jar has a symmetrical edge that pours well. (Spouts were always breaking off anyway.) The wheel made accurately spaced burnishing possible—a better finish than hand work could produce.

The true potter's wheel introduced a new principle into ancient ceramics, namely centrifugal force. "A ball of good plastic clay is placed at the center of the wheel, which is then turned rapidly either by an apprentice or by the potter himself. The action of the centrifugal force upon the ball of clay as it is modified by the fashioning hand of the potter, produces the shape. This gives to thrown pottery a liveliness and spontaneity of form that no other method can approach."² At first there was a single wheel turned by hand. Later came the double wheel, where a foot-power wheel turned the small thrower's wheel. This seems to have been a Greek improvement. The ancient potter's wheel, like the present-day one, normally ran counterclockwise. After the introduction of the potter's wheel into Palestine hand-made ware was seldom produced until recent Arab times.

The potter's wheel also produced another technique which is called turning. When a thrown-clay vessel becomes leather-hard, it can be replaced upon the wheel and then with a cutting tool some of its clay can be shaved away just as wood or steel is turned on a lathe. Thus more delicate and refined shapes could be made.

By Joseph's time Hyksos control over Palestine produced a cultural golden age. Artisans used the potter's wheel so brilliantly that they became the most skillful potters that Palestine ever produced. Indeed their pottery forms occasionally challenge the best Greek work. The Hyksos were conquered by the Egyptians c. 1550 B. C. and Egypt took over the rule of Palestine until the time of Joshua's conquest c. 1230 B. C. During these years between Genesis and Exodus Palestine declined in prosperity and the native pottery is witness to a cultural slump. A fine new foreign pottery arrived about the middle of this period. It was the famous Mycenaean pottery, known best in the Aegean area although the particular ware that is found in Palestine was more likely manufactured in Cyprus and Phoenicia.

After Joshua's conquest, the Israelites continued the traditional shapes of Palestinian pottery. They did little painting, although the preceding Canaanite phase had seen the greatest use of painting as a

² All quoted material in this article is from the authors' work on pottery technique in *Ann. American Schools Oriental Res.*, Ch. 4, vols. 21-22.

decorative motif in the entire history of Palestinian ceramics. Perhaps one of Israel's most interesting contributions was a lamp with seven wicks—a striking ceramic adaptation of the theme of the seven-branched candlestick in the Shiloh tabernacle. In the days of the Judges the land was invaded by the sea peoples of whom the most important were the Philistines. Their pottery presented fine forms and striking painted designs such as the swan pluming itself, the Maltese cross, and the Ionic spirals. The Israelite potters ignored these new painting designs but did improve the forms of their wares under Philistine incentive. By David's day Israelite pottery was on the upswing, particularly in burnished ware which exhibited a wide variety of beautiful designs.

Israelite pottery is seen at its best in the days of the divided kingdom. The following were some of the wares displayed in the pottery bazaars of the days of Jeremiah. The most expensive, because of the difficulty of manufacture, were the great four-handled banquet bowls, about the size of modern punch bowls. The lines of these bowls have a

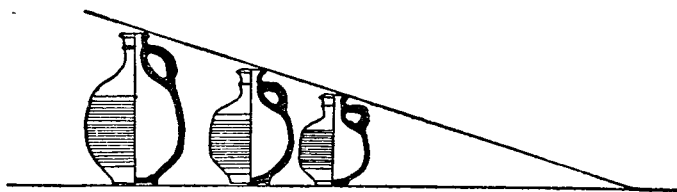


FIGURE 1.—Judean water jars, probably dating from the time of Jeremiah, which were found at Tell Beit Mirsim (Debir). Note the graduated sizes.

subtle loveliness, and on the interior their beauty is intensified by narrow spiral burnishings alternating with similarly spaced unburnished spirals. Bowls then descended in various shapes and sizes until they became as small as modern sauce dishes. Some of these are as delicate as the best modern tableware. Plates were the rarest of all Israelite dishes.

Another strikingly artistic piece was the ring-burnished water decanter (fig. 1). It is the "potter's earthen bottle" referred to by Jeremiah in his object-lesson sermon (ch. 19). Pitchers, averaging around 9 inches in height, came in three grades; superior ware, skillfully thrown and showing a vitality and spontaneity of line often missing in the more mathematically precise Greek pottery; standard ware; and cheap ware, i. e., "five and ten cent store" goods. Cups ran with or without handles and those without handles were form-fitted to the hand.

Olive oil was used in various types of cruets and elongated pear-shaped juglets. Another common use of a juglet was to hold perfume. Some juglets have perforated bottoms and were used for sprinkling

aromatic seeds upon cakes before baking. The various-sized cooking pots were the commonest pottery articles in the household. They were either wide-mouthed shallow vessels or small-mouthed ware with an almost spherical body. Both types were made with an especially heavy temper of tiny crushed stone fragments so as partly to compensate for the expansion and contraction of alternate heating and cooling while in use. Much pottery served for the storage of wine and oil. These jars might hold as much as a bath (23.25 quarts). The handles of the latter often bear inscriptions showing that they belonged to the royal Israelite treasury. A few actually bear the name of King Jehoiachin. Wide-mouthed jars were also used for the storage of grain and other dry materials. It was kitchen-sized jars of this type that Gideon used to carry his torches in the Midianite campaign (Judges 7).

The destruction of Judah's cities by Nebuchadnezzar in 588-7 B. C. was so ruthless that many of her cities completely disappeared from history and others made only a belated resurrection. Thus the exilic and post-exilic periods mark another era of depression. Native Israelite pottery shows this slump although it was offset by a good incoming Greek influence. Even before Alexander the Great, Greek pottery was invading the Palestinian market in quantity. In the Hellenistic period its influence improved the native wares. Although the Romans took over the government of Palestine in 63 B. C., their cultural influence was much slower in exerting its effect. It is represented chiefly by imported Roman pottery, especially that of the press-mold type such as Arretine ware with its intricate blending of floral and human patterns. Native ware is often characterized by a fine ribbed or corrugated effect. Present-day tourists find more of this kind than of any other ware of Bible times.

Throughout antiquity the land of Palestine was a pottery unit, although the southern section naturally showed more Egyptian influence than did Galilee and northern Transjordan, whereas the latter showed more Syrian influence than did the south. Up to the time of Abraham or thereabouts, Transjordanian pottery was almost identical with that west of the Jordan. About that time, however, a variety of influences caused the inhabitants of the country south of the Jabbok River to return to a nomadic life in which they remained until shortly before Joshua's invasion. After 1200 B. C. southern Transjordanian pottery took on some special features, particularly in decoration. From then on, its ware was more closely related to that of Syria and Arabia than to that of western Palestine.

The Nabataeans, an Arabian tribe, who became so important in Transjordan after the days of Ezra and Nehemiah and remained so through much of New Testament times, introduced a special type of pottery inspired by Greek models. It represents one of the high-

water marks of Palestinian pottery. Their finest ware is unbelievably thin and of exquisite line. Its painted ware offers something new to Palestine as it includes "stylized floral or leaf patterns" with heavy emphasis upon the grape design. The Nabataeans also used rouletted and sigillata ware, whose designs were imprinted in the clay by various methods.

Vessels of gold, silver, and copper were more precious than Palestine's ceramic wares; thus her pottery must be studied primarily as commercial ware rather than as artistic masterpieces like the best Greek ware. On the other hand, it must be pointed out that the esthetic rating of much of this ware averages higher than modern commercial ware and at times it is true art worthy of a place in a museum. Most of their pottery was red-clay ware, i. e., the finished ware had a rich red color when properly fired. Some Israelite wares were made in a glossy black finish which was produced by various techniques. White ware was usually imported.

Pottery represented one of the major manufacturing industries of the ancient world and the Israelite potters belonged to what we call today "up and coming businessmen." They had already mastered many of the economic short cuts used in present-day potteries. They created special fashioning processes so that cheaper grades of clay could be utilized. They knew the various temperatures at which to fire their ware, depending upon the impurities in the clay and the purposes for which the ware was intended. They could quickly multiply the output by combining throwing and turning techniques rather than by using the more expensive throwing only; yet at the same time the turner was so skillful one can seldom see where his work joins that of the throwers. They used assembly-line methods where different men performed different processes in the course of manufacture. They had standard styles which ran in staggered sizes, just as we do today. Pride of manufacture is shown in the use of trade-marks, particularly on cooking pots, which, after all, had the greatest market.

The pottery industry was organized in families and guilds (I Chronicles 4:23). The most difficult art for the apprentice to master was the firing of the kiln and this skill was probably passed on from father to son. "An estimate of the skill required in firing a kiln is perhaps best shown by the fact that the ancient Greeks besought the aid of the gods at this point in their work and the medieval potters offered prayers before firing their kilns."

POTTERY AS ARTISTIC ACHIEVEMENT

From the esthetic viewpoint the best pottery forms ever produced in Palestine were in the Hyksos period about the time of Joseph. Indeed, the potters of this time attained an expressive quality, a sensi-

tivity and vitality of form often esthetically more appealing than the frozen perfection of the Greeks. The Greeks attained great heights of mechanical or mathematical precision or accuracy, but the result was often cold and impersonal. Their perfection missed certain qualities of great esthetic importance: namely, sensitivity and vitality, two qualities inherent in, and essential to, any work of art. These qualities the Palestinian potter realized in his best work, and this spontaneous quality makes his work more akin to the Chinese than to the Greek.

The skillful craftsmanship of the Palestinian potter was such that one may surmise that in a Greek environment, such a craftsman would have successfully contended with the Greek potter in skillful workmanship. These potters were always skillful craftsmen and at best were artists with sufficient plastic appreciation to avoid the error or temptation to exalt craftsmanship above expressive sensibility.

While the Palestinian potter was not attempting to achieve an object of luxury and was concerned only with making a useful pot, nevertheless he also made a beautiful pot. The artistic qualities he attained were the direct outcome of his rapid method of production which gave a spontaneity and vitality to his forms and contours. He refrained from overdoing perfection or attempts to "gild the lily." He was content to let "well enough alone," perhaps because he was not making a luxury item, but a pot to serve the needs of his patrons. In this objective he was admirably successful.

DECORATION OF POTTERY VESSELS

Both the Canaanite and the Israelite potters, however, had one major shortcoming! They did not employ glaze. This indictment against the Palestinian potter is the more serious, for even before Abraham's time they had used a slip which was very close to a true glaze. Although they did not follow up this lead and produce a true glaze, it is the only major ceramic process which they did not master.

In the field of ceramic decoration their major methods were the use of slip, burnishing, and painting. The use of slip in ceramics is related to the use of plating in metallurgy. Just as we put a thin coating of silver over a cheap metal base and thus get a finish which looks like solid silver, so the potter can put a thin coating of a superior clay upon a cheaper ceramic body and then the fired ware will look as if the piece were made of superior clay throughout. In practice, however, slip was usually employed only on that part of the ware which was easily seen. Slip also permitted color variations and this was important since most Palestinian clays were ordinary red clay. The cheapest form of "ceramic veneer" is called wash. This is applied

to the ware after it comes out of the kiln and thus, like calcimine on a wall, it will wash off when water is applied.

Burnish leaves something of a glazelike finish although it is in no way related to a glaze. It is sometimes miscalled polish by careless writers. "Burnishing is done by sealing the surface pores of the leather-hard clay by pressing them in with a pebble, or a tool of metal or bone. This effect is secured either by holding the bowl in the hand, or by pressing the burnishing tool against the vessel as it spins upon the wheel. In polishing, the surface clay is removed from the ware, but in burnishing the surface clay is pressed gently into the ware."

The painting of pottery began as early as neolithic times, but was seldom used as widely as burnishing. The late Bronze Age was the most prolific in its use, and after that period Transjordan was more favorable toward it than western Palestine. White, black, and red are the most common colors; blue, purple, yellow, and orange are rare. The majority of their colors were probably native earths such as the umbers and ochres. Ceramic painting presents some special problems. The clay surface is absorbent and therefore no corrections can be made upon it. The painting "must be spontaneous, swift and complete, otherwise the clay absorbs unequal amounts of paint at different points, and the accuracy of the line is ruined. A line cannot be retouched, for the point of correction will show a blot. Thus the painter must have every detail of his composition definitely fixed in mind before he puts his brush to the clay. Also since much pottery has a circular surface, the design must be so well conceived and executed that the point of juncture is not noticeable." If the ware is to be fired after painting, then the colors will be changed in the kiln and the artist must work out his composition with his finished colors in mind rather than with the actual colors he places on the clay surface.

HOUSEHOLD IDOLS IN CLAY

There is still another important field of ceramics for Old Testament students and that is the heathen household gods. These little pottery idols are of two types. The earliest is a plaque, which was used by the Canaanites before Joshua's conquest. It is elliptical in shape and about 3 inches in length. It portrays in bas-relief the naked Canaanite mother-goddess of fertility. She usually holds in her hands the lotus blossoms which are one of her symbols. She generally wears an Egyptian headdress with long curls over the ears. She apparently borrowed this from her Egyptian relative, the goddess Hathor. The second type of idol is the "snow-man" type, which came into Israel by way of Phoenicia and continued until the destruction of Jerusalem. These are the household idols so vividly condemned by the prophets.

These idols represent a new technique in pottery manufacture. It is the press-mold type of work. The older plaque idol was made by impressing a lean wet clay upon an intaglio mold of the goddess. When the clay had dried sufficiently to shrink away from the mold, the plaque was set aside to dry thoroughly, after which it was fired like any other piece of pottery. The snow-man type was a two-piece job; the head was made in a press-mold and the body was modeled freehand; the two were then joined while leather-hard. Other pottery cult objects used in the worship of the Canaanite fertility goddess were bulls, doves, and small stylized trees with a lamp in the branches. The snake is another member of her cultic family and often appears as decoration on the vessels used in her worship. Two-story pottery shrines have been found as well as a multiple-storied incense altar where lion stands upon lion.

OTHER USES OF POTTERY

Pottery objects were used from the cradle to the grave. At one extreme of life they furnished toys for the children, such as war horses for the boys and dolls and tiny cooking pots for the girls. Pottery even furnished the feeding bottle and the rattle for the baby's entertainment. At the other end of life pottery caskets were sometimes used for the dead.

Industry made use of pottery tools, such as the loom weights of the weaver. In Israelite times these were always doughnut-shaped but came in many sizes. If the siege of a city lasted too long and the army ran out of sling stones, they would bake clay balls of similar size and use them as substitutes. The soldier carried a pottery canteen which was so made that it kept the drinking water cool.

Both the businessman and the diplomat in patriarchal times wrote with a stylus on clay tablets. If the documents were especially valuable they would be fired in a kiln and thus become imperishable pottery whose contents could never be tampered with. Even maps were drawn on clay long before Abraham's time.

Pottery was used as illustrative material by the prophets and preachers of Bible times. Some of the more important passages are: Psalms 2: 9, Isaiah 45: 9, 64: 8, Jeremiah 18: 1-5, 19: 1-13, Zechariah 11: 13, Matthew 27: 7-10, Romans 9: 20-24.

Cheap jewelry and gaming pieces were sometimes made of clay as were the buttons and spindle whorls of the poor. In the days of Jesus even theater tickets were pottery pieces. It was the pottery lamp that gave light to the house at night and the pottery brazier that warmed it in the winter. The lamp often went to the cemetery and was buried with the dead.

Even broken dishes have their work to do. Larger fragments served

as scoops or dippers. In them coals were carried from one kitchen fire to another (Isaiah 30:14). They took the place of papyrus and in Samaria the Israelite government even used potsherds on which to write tax receipts. The precious Lachish letters which show us Hebrew writing from Jeremiah's day are military correspondence written upon potsherds. One of the nuisance jobs of a Palestinian archeologist is the daily dusting of thousands upon thousands of potsherds to see if perchance any writing may be preserved upon them. So seldom does one find writing in Palestinian excavation that this is not a waste of labor.

The final utilitarian end of broken pottery was to be ground up and mixed with waterproof plaster to be used for lining cisterns. Potsherds, however, were so numerous in antiquity that they constituted a good percentage of the debris of all ancient cities. There they speak their own language to the professional archeologist who digs them up today. They recount the history of the ancient cities where they lie. They date their historic vicissitudes, their economic prosperity, their cultural changes, the march of invading armies, the religious life of the people, the manufacturing skills of the times, the esthetic standards of the average man. In fact, they present a cross section of the world of the Bible.



1. Potter turning a dish on a simple wheel. This figure, found in an Egyptian tomb which is dated c. 2500 B. C., was one of a large group of servants who were supposed to minister to the soul of the person with whom they were buried. (Oriental Institute of Chicago.)



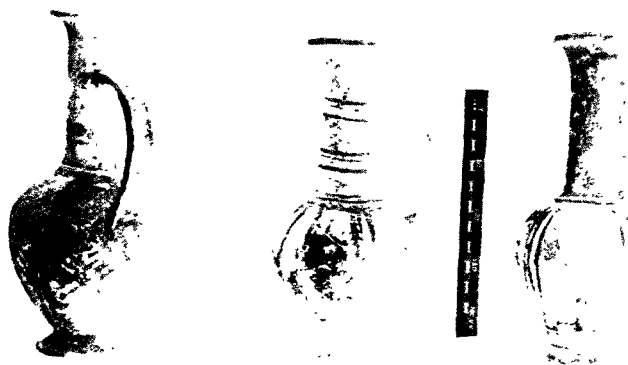
2. A cellar or pantry filled with jars of grain, found in the ruins of Beth-shean, and dated about the time of David. The house in which the jars were stored was destroyed and the crumpled walls preserved the contents of the pantry. (From Grant and Wright, *Am Sheims Excavations*, pt. 4, pl. 12, p. 2.)



- 1 Sorting potsherds (fragments of pottery) after a day's excavation at Bethel in 1934. Each basket is labelled so that it is known just where each sherd was found. The fragments are important for dating purposes. Left to right: The Rev. Lester E. Williams, Drs. G. Ernest Wright, Joshua Starr, I. Ben-Dor, Ovid R. Sellers (only his hat is visible), and an Arab boy who spent his time washing the pottery.



- 2 Bowls, dating from the seventeenth or sixteenth century of the Middle Bronze Age, which were found by Elihu Grant at Beth-shemesh.



- 3 Three vases ("lilbils") imported from Cyprus c. 1600 B. C. They were found by Elihu Grant in a tomb at Beth-shemesh. The ware has a hard, grayish-black texture and when struck gives off a metallic sound. Pottery of this sort was imported in large quantities between c. 1600 and 1250 B. C.



A LARGE STORAGE JAR, DATING FROM ABOUT THE TIME OF JEREMIAH, WHICH WAS FOUND IN THE RUINS OF BETH-SHEMESH

(From Grant, *Am Shems Excavations*, pt. 1, pl. 1)

THE MARCH OF MEDICINE¹

By M. M. WINTROBE

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THE ORIGINS OF MEDICINE

The progress of medicine, as might be expected, has been closely tied with the advance of civilization. The Golden Age of Greece, the Roman period, the Dark Ages, the Renaissance are all reflected in the history of medicine for in these same periods medicine advanced or declined as did civilization itself. But the opposite was also true. Civilization declined in part as the result of disease. Malaria contributed in a large measure to the decadence of Greece. The Greeks who surrendered to the Roman legions were very different from those who had fought off the Persian invaders. Malaria, according to Jones (1)², an outstanding student of Greek medicine, changed them from brilliant, energetic, original individuals full of initiative, high spirit, and patriotism to vacillating, weak, cowardly, and selfishly cruel ones. No doubt other factors played their part as well but there is no question that a disease like malaria can sap the vitality of a people. In later years, the great plagues and epidemics were calamities which impeded civilization for centuries. The economic advancement of many parts of the world today is greatly retarded by the prevalence of disease.

In the medicine of Ancient Greece we see the dawn of scientific medicine. This refers not to the mythical Asclepios (Aesculapius) and the legendary serpent, or to the medicine of the sanctuaries and of the priests, but to the emergence of the practice of direct observation. Before this period medicine was variously empirical, magical, priestly, or religious. There had been no concern with the discovery of fundamental causes and there was no attempt to arrange in logical sequence the cause and effect of observed phenomena. The development of scientific medicine was contemporary with the emergence of Greek philosophy. Comparable with Pericles, Herodotus,

¹ Ninth Annual Reynolds Lecture. Reprinted by permission from the Bulletin of the University of Utah, vol. 35, No. 12, January 17, 1945.

² Numbers in parentheses indicate references at end of article.

Thucydides, Phidias, Sophocles, and Euripides, was Hippocrates. He was undoubtedly the most important and most complete medical personality of antiquity (2). He was born about 460 B. C. on the small island of Cos.

Objective observation was the feature of the Hippocratic school. It has been stated that the 47 clinical histories contained in the Hippocratic writings are the only ones worthy of the name to be found in medical literature for the next 1700 years (3). The honesty and sincerity of Hippocrates is illustrated by his citing the fact that 60 percent of his cases ended fatally. In his own words, he believed it "valuable to learn of unsuccessful experiments and to know the cause of their failure." He made no attempt to magnify his own importance by hiding his own lack of knowledge or failures. The "Oath of Hippocrates," now familiar even to some lay persons, expressed the high ethical level to which medicine rose in the Golden Age of Greece.

The inspiring period of Hippocrates was followed by an astoundingly long period of stagnation and decadence, interrupted only by rare and relatively minor contributions. One of the few outstanding figures was Galen (A. D. 131-201), physician to the Emperor Marcus Aurelius. To Galen are attributed wide and original discoveries in anatomy, physiology, and disease in general as well as in the use of various drugs. But this was a very different manner of man, who was equipped with the highest opinion of his own value and was sure of his own infallibility. He constructed an extensive edifice of dogma.

With pestilences mysticism returned. The viewpoint which made disease the punishment for sin was no stimulus to the search for the causes of disease. For centuries none disputed the oracular pronouncements of the past even though illustrious physicians appeared from time to time. The Persian philosopher, Avicenna, was the most renowned of the Golden Age of Arabian medicine in the tenth century. His famous Canon (Q'anun) followed the ideas of Hippocrates, Galen, and Aristotle and constituted a statement of authoritative scholastic dogmatism.

MEDICINE AND THE RENAISSANCE

The reawakening of a critical spirit, the rebellion against authority, the promulgation of the system of Copernicus, the discovery of America, and events of similar magnitude during the Renaissance were accompanied in the field of medicine by a violent revolution against the authority of the ancients. The beginning of the modern experimental period may be said to date from Paracelsus, a strange combination of sorcerer, philosopher, alchemist, and physician of this time. The keynote of the teaching of Paracelsus was that men should search into the workings of nature for themselves. He startled

the world by publicly committing the Canon of Avicenna to the flames of a students' bonfire.

This period was marked by the work of Vesalius who laid the foundations of modern anatomy, William Harvey who discovered the manner of circulation of the blood, and Thomas Sydenham who demonstrated the value of accurate description of the signs and symptoms of disease in the place of vague theories. The Italian, Morgagni, laid the foundations of morbid anatomy by examining great numbers of bodies after death. He carefully and systematically recorded everything which he found abnormal and tried to correlate this with the signs and symptoms in the individuals before they died. The best type of medical practice requires this even today, for our knowledge is still very incomplete.

The new approach in medicine gradually proved its value. Following the example of his teacher, John Hunter, Edward Jenner had the courage to test the Gloucestershire tradition that milkmaids who had contracted cowpox from milking did not get smallpox. Countless lives have been saved and much disfigurement and blindness prevented by the method of vaccination which developed from Jenner's simple experiment. The discovery by James Lind of the importance of fruit juices in the prevention of scurvy was significant not only medically but also politically and economically, for the might of the British Navy depended on the health of the British "limeys," as their sailors came to be called.

EIGHTEENTH-CENTURY HOSPITALS AND SANITARY CONDITIONS

But progress was extremely slow. In the eighteenth century, hospitals were for the care rather than the cure of their inmates. So prevalent were erysipelas, pyemia, septicemia, and gangrene in these institutions that they came to be known as the "hospital diseases." Such pestilences would come upon the patients and kill them like flies. At the Hotel Dieu in Paris, six unhappy patients, in various states of physical and mental disorder might be heaped all in one bed. No one who had a home would go to a hospital; nor did they need to, for after all such hospitals offered no facilities except for the spread of disease.

Sanitary conditions were equally horrible. In the towns of eighteenth-century England the streets were made as narrow as was feasible and were often barely passable from mud or tolerable from stench. "In places where house drainage was connected up with sewers these generally ran directly into the local river, canal, or stream with the natural result that such water became a stinking open drain." (4) Water was inadequate in supply. While famine and leprosy and plague were no longer as important factors as they had been, intermittent and remittent fevers, dysentery, malaria, typhus, scurvy, cholera, yellow fever, influenza, measles, diphtheria, and scarlet fever were rampant.

THE MICROSCOPE, THE ANIMAL CELL, AND THE GERM THEORY

Thus, although medicine gained an impetus in the Renaissance, progress was slow. The new advances had to await the discoveries in other fields of science—physics, botany, and chemistry. The great physicians had developed their powers of observation to a high degree, but this did not suffice. It was necessary to amplify the powers of the sense organs, and particularly those of sight.

The invention of the *microscope* has been attributed to Roger Bacon, who lived in the thirteenth century, but Galileo, in the seventeenth century was perhaps the first scientific user of this instrument. To the spectacle makers, however, we owe the development of the microscope, and particularly to Antoni van Leeuwenhoek, a man who had never attended a university and was entirely self-taught. He constructed a number of microscopes and studied all types of matter, even including the red blood corpuscles whose diameter he measured.

A decisive factor in medical progress was the discovery of the *animal cell* and the establishment of the fact that the living body is a vast organization consisting of innumerable individual cells so small that they can be seen only with the aid of a microscope. Schwann, and later Rudolph Virchow, applied the discoveries of the botanists, who had demonstrated the cellular constitution of the vegetable kingdom, to the intimate study of disease. This was the foundation of the science of pathology.

There is no doubt that one of the most important contributions of the nineteenth century to medicine was the demonstration of the fact that invisible organisms, so small that they can only be seen with the aid of a microscope, may cause disease. Such organisms had been observed in the seventeenth century but two centuries had passed before their significance was appreciated. In the nineteenth century, thanks to the work of Pasteur, Koch, and others, a revolution in the structure of medical thought occurred. It was finally recognized that infinitely small organisms, endowed with special pathogenic qualities, may play a preeminent role in producing disease.

At the same time that Virchow was laying the foundations of pathology in Germany, Pasteur developed the *germ theory* in France. Pasteur was a chemist and in that field his earlier studies led him to the discovery that putrefaction is a kind of fermentation and that both these processes are due to micro-organisms. He showed that the disease of wine which plagued the wine industry in France was due to the action of microbes and that by heating the wine for a short time to a temperature between 50° and 60° C., the fermenting agent could be destroyed while the wine would remain unaltered and would keep indefinitely. This process is now well known under the name "pasteurization."

A name equal in importance to that of Pasteur in founding the science of bacteriology is that of Robert Koch. This man was a district physician in a small Prussian town. His thoughtful wife gave him a microscope on his twenty-eighth birthday. We owe her a very great debt, for Koch went to work studying anthrax, a disease common among the sheep and cattle of his agricultural district, and thus initiated a series of investigations which revealed the causes of a great number of diseases, including tuberculosis. Before the close of the nineteenth century there had been discovered the causative agents of gonorrhea, suppuration, typhoid fever, malaria, cholera, diphtheria, certain types of pneumonia, cerebrospinal meningitis, Malta fever, tetanus or lockjaw, plague, botulism, and dysentery.

The story of the attack on germs, once they were recognized, is an exciting and fascinating one. Investigators became interested in the method of spread of organisms. There were many proponents of the idea that the air is bad and that in this way organisms causing disease are transmitted. It has been aptly stated (4) that it was easy to blame the air since no one owned a vested interest in it. It was more dangerous to find fault with the water supply, for this had its sturdy champions in the directors of the various water companies. Yet in many places the water supplies were nothing more nor less than diluted sewage.

It is well known now that tuberculosis, diphtheria, undulant fever, typhoid, and a number of other diseases can be transmitted by infected water, milk, or other foods. Yet it has not been easy to convince people of this fact and many communities still tolerate laxity in sanitary legislation. Special interests concerned only with financial gain and officials unaware of the importance of sanitation are permitted to take risks with human life.

The newer knowledge of the bacterial causation of certain diseases naturally led many to wonder why only certain individuals were attacked by such bacteria and why even when attacked some did not succumb. It had been recognized for centuries that individuals attacked by certain diseases were not likely to be attacked again. Study of the mechanism whereby the body is able to withstand the action of bacteria led to the development of the science of immunology. Once some knowledge was gained of the protective mechanisms which we possess, scientists were challenged by the problem of developing and improving this protective faculty. Thus have come antitoxins, serums, and vaccines, and the saving of countless lives.

THE DEVELOPMENT OF SURGERY

In Roman times each soldier kept with him a kit of bandages for use on himself or for a wounded or bleeding comrade. Such measures served well enough for minor injuries. Those who were so badly

wounded that they were unable to move along with the advancing troops were put to the sword. The able-bodied but wounded soldier who fell into the hands of the enemy could only expect to be insulted or mutilated, if not killed. During the Middle Ages some men of doubtful qualifications made it their trade to treat soldiers for a meager stipend just as mercenary soldiers took up warfare as a business. Field hospitals were introduced by Isabella of Spain around 1487, and they were later reintroduced by her grandson at the siege of Metz in the sixteenth century. There Ambroise Paré was a central surgical figure. He was responsible for abolishing the custom of applying cautery or boiling oil to wounds. In the seventeenth century the regimental surgeons were still referred to as staff barbers and that is about what the great majority of them were.

The development of surgery was hampered by the lack of means for controlling pain and it was plagued by the high mortality which attended it. Such surgical deaths were due to hemorrhage, traumatic shock, and infection. Infection was a concept wholly unfamiliar before the nineteenth century. A favorite method of procedure of eighteenth-century surgeons, as well as of those who preceded them, was to probe wounds. The probes were not sterilized and often were not even washed. The surgeons themselves wore their oldest frock coats in the operating room. To these coats, often heavily encrusted with dried blood and pus, some surgeons even attached an aura of superiority.

Surgery in the eighteenth century consisted of the setting of broken bones, the probing and suturing of wounds, the amputation of crushed or gangrenous limbs, and the opening of abscesses. No one dared to attempt abdominal surgery. Operations for gall-bladder disease, thyroid disease, and cancer, which make up so large a part of a surgeon's work today, were unknown. Appendicitis had not been recognized.

It was at the turn of the eighteenth century that one of the many dramatic events in the history of surgery took place. In Danville, Ky., on Christmas Day, 1809, Ephraim McDowell performed in his own home an operation such as had never been done before. This was the removal of a large abdominal (ovarian) tumor, without the benefit of anesthesia, and without the aid of adequate methods for stopping hemorrhage or for preventing infection. Since her life depended on it, his stalwart patient agreed to undergo the ordeal. McDowell's fellow citizens also knew that the operation was experimental, and it is told that a crowd gathered outside of his house with the intention of hanging him if his patient should die. Fortunately for McDowell, and for the progress of surgery, the operation took no more than 25 minutes and the patient recovered completely.

This amazing performance found few imitators, for it required extraordinary courage on the part of both the patient and the surgeon. We may be proud that the problem of relieving pain was solved by two Americans who quite independently of each other in the early 1840's discovered the anesthetic powers of ether. One was Dr. Crawford W. Long, a general practitioner in a little town in Georgia. He first operated with ether anesthesia in 1842. He did not publicize his discovery, and the credit for making the use of ether known to the world is given to the Boston dentist, William T. G. Morton, and to the staff of the Massachusetts General Hospital, where the regular use of ether began in 1846.

To Joseph Lister must be given the credit for initiating the conquest of surgical infection. In 1872, at the Bellevue Hospital in New York, from 40 to 60 percent of all amputations of limbs proved fatal. The same was true at the University of Glasgow when Lister took the post of professor of surgery there. Lister was impressed by Pasteur's demonstration that organisms that produce fermentation and putrefaction are carried on particles of dust in the air. He decided to try to prevent infection by using on wounds a dressing containing a material capable of destroying micro-organisms. Using crude carbolic acid, he developed the first antiseptic dressing in March 1865. Two years later he was able to report a total of 11 cases of compound fracture treated by the antiseptic method, with 9 recoveries, 1 amputation, and 1 death. Pyemia, hospital gangrene, and erysipelas disappeared. These were unprecedented results, as dramatic in their day as any we are seeing today.

An equally important contribution was Lister's discovery of a method of preparing a relatively sterile, absorbable catgut with which wounds can be sewed. This procedure made it possible for wounds to heal in the clean and straightforward way to which we are accustomed today. Until this time pus formation was so common that it was regarded as part of the healing process and was spoken of as "laudable pus."

We can now appreciate how great were Lister's contributions to humanity. In his time, however, he met much opposition. His untiring investigations on ligatures were carried out in animals and the Anti-Vivisectionists in England made repeated attempts to prevent him from continuing his experiments. Furthermore, his own associates were too stubborn to appreciate the value of his discoveries, and as late as 1880 in all the British Isles there were only one or two clinics where his methods were used. Fortunately, in Germany and subsequently in this country, a number of surgeons began to apply his methods and to find them of the greatest importance. The German surgeons not only adopted Lister's methods but they developed the

essentials of the modern aseptic technique which is actually quite different from Lister's antiseptic method. They showed that the dangerous or so-called pathogenic bacteria were conveyed to wounds by the hands of surgeons and nurses or by instruments and dressings. Boiling was discovered to be an effective means of sterilization. It is significant, however, that as late as 1883, 18 years after Lister's discovery, as Haagensen and Lloyd (4) record, "In the discussion of a paper on Lister's doctrine before the American Surgical Association, leading surgeons from many parts of the United States almost without exception condemned his methods, saying that they had tried them and had no success with them. The truth, of course, was that they had not tried them out with the requisite attention to detail, and so they failed."

At the Johns Hopkins Hospital there are two buildings of interest at this point in our story. One is the Halsted Clinic, which is the surgical building, and the other is Hampton House, the nurses' home. At Johns Hopkins the first Professor of Surgery was William Stewart Halsted and at that time the nurse in charge of the operating room was Caroline Hampton. She complained that the solution of mercuric chloride used for rinsing the hands before scrubbing, caused dermatitis. Dr. Halsted had the Goodyear Rubber Co. design a pair of rubber gloves for her. Their advantage from the viewpoint of protecting the patient from infection introduced by the operator became obvious and they have been used ever since. It is significant, however, that Dr. Halsted and Miss Hampton were married shortly after this glove episode. It has been suggested that, "This discovery, certainly one of the most important means of avoiding wound infection, was perhaps not entirely the result of scientific zeal" (4).

Halsted proved to be a quiet but effective force in this country in transforming surgery from a series of dramatic and somewhat dangerous incidents into a less conspicuous, painstaking, and more successful method of treatment. He developed means for the control of hemorrhage during operation which gave to the surgeon, in Halsted's words, "the calm which is essential for clear thinking and orderly procedure at the operating table." He, as well as Crile of Cleveland, taught the importance of gentle handling of the tissues. He devised operative techniques which are still followed today.

It would be impossible to discuss all the advances which have been made in surgery since the latter part of the nineteenth century. The recognition of appendicitis as a disease entity and its surgical treatment have saved thousands and thousands of lives. The advances in operative surgery of the gastrointestinal tract, in operations on the female genital tract, in thyroid surgery, in orthopedics, in neurosurgery, and, only very recently, in chest surgery have been truly

phenomenal and have saved countless lives and prevented untold suffering. In spite of a very great increase in the amount of surgery performed, and in the extensiveness of operations in which surgeons now engage, the over-all operative mortality in one of the better hospitals in this country dropped from 16.5 percent in 1889 to 2.1 percent in 1939 (4). These advances, as well as other discoveries which will be mentioned later, have profoundly influenced the prospects of the battle casualties of the present day.

THE EVOLUTION OF DIAGNOSTIC METHODS AND OF OUR UNDERSTANDING OF DISEASE PROCESSES

Less dramatic but equally important have been the advances in methods for recognizing disease and in the understanding of the disturbances which various diseases produce. The early physician had to rely solely on his senses of sight, touch, hearing, and smell. Although his powers of observation were developed to a high degree, and necessarily so, the interpretation of his findings was often erroneous because his knowledge was so limited. Examination of the pulse was practiced even by the early Egyptians. Temperature was estimated with the hand applied to the chest. Santorio, an Italian of the sixteenth century, was perhaps the first to use a thermometer, but until the nineteenth century the apparatus available was cumbersome and was used by very few. The thermometer is one of the first instruments of precision to aid medical practice, but it did not become a necessary part of the physician's armamentarium until the time of Wunderlich in the latter half of the nineteenth century. The modern simple instrument was only devised in the present century.

Examination of the urine was also practiced in the early days of medicine. The Arabian physician, Avicenna, wrote lengthily on the subject. Uroscopy or water-casting, as it was called, became such a regular practice that the urinal became the emblem of the physician in the Middle Ages and was a favorite theme of the painter and wood engraver. Sometimes the urine was carried to the physician by a messenger and the diagnosis made "by mail order." Although this method had no true diagnostic value, it was pushed to fantastic extremes and led to the most far-reaching conclusions. It was not until the late nineteenth century that the chemical procedures for the examination of the urine and of the blood, which we now use, were developed.

Tapping of the chest, which is so familiar today and which has proved to be a very valuable aid in physical diagnosis, was received with ridicule and sarcasm in 1761 when Leopold Auenbrugger proposed the procedure. It is interesting that he was led to this discovery when he observed that the level of fluids in his native wine casks could

be ascertained by thumping. Auscultation, that is, listening to the chest, was practiced by Hippocrates and was aided by shaking the chest. This was done by placing the ear to the chest until Laënnec (1817) invented the first stethoscope. He gained his idea for the use of a hollow tube by observing children listening to the sound of taps on hollow logs.

The X-ray was discovered in 1895 and, like so many other discoveries, had its beginning in an accident. It was by mere chance that Roentgen was working in the dark with a tube of glass containing various gasses at low pressures (the Crookes' tube) and happened to notice that a small piece of paper covered with a coating of barium plantinocyanide shone brightly. Fortunately he had the foresight to suspect that this might be of importance and the persistence to investigate the possibilities until he obtained convincing evidence of the value of these strange rays. This discovery was one of the most dramatic events in the history of science. As an example of how the imagination of the world was stimulated by it, the bill may be cited which Assemblyman Reed, of New Jersey, introduced in the State legislature in 1896 to prohibit the use of X-ray opera glasses in theaters.

In the nineteenth century knowledge of disease was sought mainly through studies of morbid anatomy; that is, by observing the effects which disease produced on the tissues. Gradually interest developed in the study of the ways in which the functions of the body are disturbed in disease—pathologic physiology and biochemistry. This approach bore fruit because with better understanding of disease processes methods were developed whereby disease may be recognized much earlier than it once could be. Furthermore, such knowledge has led to the discovery of methods of treatment which are directed at the primary cause or at least correct the abnormality which has been produced.

Advances have been made in so many fields that it would be impossible to discuss them all here. Many problems relating to man have been approached through experiments in animals, and it is safe to say that they would probably never have been solved otherwise. An example is found in the story of the conquest of diabetes.

In 1920, Frederick Banting, a physician in London, Ontario, while preparing a lecture at the Western Ontario Medical School on the relation of the pancreas to diabetes, ran across the report of a rare case of stone in the pancreatic duct. The author of that report pointed out that blockage of the pancreatic duct by the stone had caused atrophy of all the pancreatic cells except certain small groups known as the "islets of Langerhans." These were the cells which were known to be damaged in persons suffering from diabetes. In the case cited, diabetes had not developed.

It had been known for more than 30 years that the pancreas was related to diabetes and a number of investigators had attempted without success to isolate the secretion of the cells contained in the islands of Langerhans. Banting was struck by the thought that by tying the pancreatic duct of animals it might be possible to obtain the secretion of the islet cells and that an extract of the cells might actually relieve the high blood sugar found in diabetes. He was so obsessed with the idea that he got up at 2 in the morning and wrote three sentences in his notebook. "Ligate pancreatic duct of dogs. Wait 6 to 8 weeks for degeneration. Remove the residue and extract."

It is significant that when he went to Toronto to talk to the professor of physiology there, Dr. J. J. R. MacLeod, he got little encouragement. Some years later this same MacLeod, together with Banting, received the Nobel Prize for Banting's great discovery. Fortunately, Banting's determination won out and with the aid of a medical student, Charles H. Best, he succeeded in making an extract of the islets as he proposed. Banting and Best operated on the first dog on May 16, 1921. By January 1923 insulin was being successfully used in the treatment of human diabetes in a number of clinics in Canada and the United States.

The discovery of the treatment of diabetes is closely linked with that for pernicious anemia, for George R. Minot, who is mainly responsible for the latter, himself was suffering from diabetes and might not have lived to make his important studies in pernicious anemia. This disease was so called because until 1926 it inevitably led to death. The story of Minot's success is one of painstaking study, patient observation, and persistent effort in the face of personal ill health as well as frank skepticism and even open criticism from his colleagues. It was naturally not easy to accept the idea that a pale, exhausted-looking patient must consume a half pound of liver daily and could expect to get better thereby. It was indeed a great surprise to discover that after only a few days of liver therapy such a patient craved food, color appeared in his face, and his outlook had changed. The development of an extract of liver which is so potent that one injection per month or less often is sufficient to maintain such a patient in normal condition is the natural outcome of the researches which Minot's perseverance initiated.

The story of the vitamins is another impressive chapter in the history of medical science. Deficiency diseases have been known for a long time. Scurvy hampered the crusaders and ravaged the sailors of Vasco da Gama and of Cartier. It came to be known as "the plague of the sea and the spoyle of the mariners." The Spaniards and the Italians knew pellagra and recognized that it was associated with the eating of unsuitable food. Glisson described rickets, which term is

derived from the old English verb meaning "twisted," in 1650. Beriberi ravaged the Japanese Navy at the turn of the last century and plagued the Philippines for many years.

That there exist substances necessary to life although required only in relatively minute amounts is, however, a relatively new concept. The term "vitamin" was introduced in 1911. For many years these substances were so mysterious that the letters of the alphabet were used to name them and they were known only by the effects of their absence. Their total number in those earlier days was not even suspected. Today, when we know the chemical formulas of more than 14 of these remarkable substances, it is recognized that still others remain unrevealed. The demonstration of their widespread physiological action and of the effects of their administration in conditions of deficiency has been one of the most important achievements in the present era.

This newer knowledge has been worked out for the most part in animal experiments. The first experimentally produced deficiency disorder came about largely by accident. In the Dutch East Indies, Eijkman was engaged in certain experiments with chickens when his stock diet of chicken feed ran out. He was forced, as a consequence, to give them the table scraps from the adjoining hospital. Since the diet of the natives consisted almost exclusively of polished rice, this is what the chickens received. Great was the surprise when the chickens developed a disorder resembling the beriberi which was so prevalent in the East Indian Islands. Eijkman soon found that the skin of the rice kernel or even the rice bran relieved the condition in the chickens. Thus was the first of the "B" vitamins discovered.

The rat became the favorite animal for experiments in nutrition. The chick, the dog, the guinea pig, and more recently the rabbit, the pig, the mouse, and the hamster, and even bacteria have played their role in advancing the science of nutrition. We have learned how vitamin A is important for vision and how night-blindness develops in its absence; how important thiamin is for the heart, and we have seen the extreme shortness of breath that develops in the pig in its absence; how riboflavin is concerned with growth and with the eyes, for in its absence cataract may develop; how sick dogs became in the absence of niacin. We have seen pigs lacking vitamin B₆ suffer from severe convulsions, become extremely anemic, and develop a peculiar gait. It has been shown that the hair of the black rat turns gray in the absence of pantothenic acid and that the pig becomes bald, ceases growing, and becomes unable to walk. We have learned how in a guinea pig lack of vitamin C leads to serious hemorrhages in the tissues, and death; how the rat in the absence of vitamin E becomes sterile and the rabbit develops certain peculiar changes in the muscles; and how the chick lacking vitamin K is the victim of a severe

hemorrhagic state. The chemical structure of many of these substances has been discovered. Great strides have been made in understanding their mode of action. This has meant learning in detail about the finer chemical processes on which life and growth depend.

It has been demonstrated, too, that various species of animals differ in their needs for the different vitamins and that the manifestations of deficiency are not always the same in all animals. As far as man is concerned we have already learned about the dramatic effect of niacin in pellagra and the importance of vitamin K in certain types of hemorrhage, while man's need for vitamin C and vitamin D are by now old established facts. But there is a great deal with reference to man which is still unknown, a fact which those seeking financial gain by the sale of vitamins choose to ignore. Much has been claimed for which there is no adequate scientific basis. In no field has the public been given so distorted a picture as in that of the vitamins.

THE PRESENT-DAY "WONDER DRUGS"

When the present era of medicine will be history, it will probably be called the "Therapeutic Period." As one scans the development of medical knowledge since the Renaissance, three earlier periods can be made out. The first is the Anatomical, when students of medicine sought to learn about the structure of the human body. As this knowledge was gained, curiosity was aroused as to the manner in which these organs function—the Physiological Period. The study of the structural abnormalities produced by disease was closely correlated with a search for the causes of disease and the study of the mechanisms whereby disease is produced. This may be designated as the Etiological Period. Obviously these periods are not sharply separated from one another nor can the study of structure, function, causes, and mechanisms be regarded as now completed. These divisions follow one another naturally, however, and the knowledge so gained is a necessary prerequisite to the development of intelligent and effective methods of treatment.

The fantastic methods of treatment which were practiced in the earlier days of medicine, like the criminal hokus pokus of the charlatans and quacks of today, were founded in ignorance and flourished thereby. The advances in our knowledge in the last 75 years have been so great that it has been possible to devise for certain diseases specific methods of treatment, and to apply such methods with understanding. The advances in surgery have been described already; the development of antitoxins, serums, and vaccines has been mentioned, and the discovery of such substances as insulin, liver extract, and the vitamins has been discussed. The most dramatic advances of all have been made in the field of chemotherapy, by which is meant the treatment of disease by specific drugs.

Some years ago at the University of California there was a celebration commemorating the three hundredth anniversary of the introduction of quinine, in the form of Peruvian or Jesuit's bark, into medicine. On that occasion the late Dr. William H. Welch said that the introduction of this drug into medicine was as important as the whole concept of infectious disease because prior to its discovery all forms of treatment were directed either to purging, to sweating, or to causing increased urination in the patients in the hope of expelling evil humors.

Modern chemotherapy had its beginnings in the work of Paul Ehrlich, at the turn of the present century. This diligent investigator devised the technique of synthesizing many new drugs of slightly varying chemical formulas and testing each experimentally. He began by studying the effects of drugs in destroying a unicellular organism, a trypanosome which had just been discovered to be the cause of a disease of horses and which could be transmitted for experimental study in mice. When, not long after, the cause of syphilis was revealed, he was prepared to attack the spirochete in the same way. The story of Ehrlich's epoch-making contribution is one of incredible tenacity. It was his six hundred and sixth arsenical compound, salvarsan, which had the desired effect.

Ehrlich's object was to sterilize the body of the parasites without injuring the body tissues. He sought to do this by giving the experimental animal or the patient a substance which could be taken internally, and thus his purpose differed from that of Lister who proposed to destroy bacteria which might have reached an external wound, or that of the "aseptic" school which tried to prevent access of bacteria to a wound. Ehrlich's task proved to be a difficult one, for neither "606" nor his later compound "14" accomplished such internal sterilization without sometimes causing grave injury to the patient. Nevertheless these agents have proved to be extremely effective for the treatment of syphilis and the risks involved have been far surpassed by the results accomplished.

It was not until more than two decades later that another compound was found equal in importance to the organic arsenicals produced by Ehrlich. It is significant that the methods used for the discovery of the new drug were essentially the same as those devised by him. As long ago as 1915 two American workers (4) studied the bactericidal properties of a large series of azo dyes including several sulfonamide compounds. They limited their observations to the action of the dyes upon bacteria in the test tube and they did not study the effect of these dyes in animals. It remained, therefore, for Dr. Gerhard Domagk, at the I. G. Farbenindustrie in Germany, to discover an effective chemotherapeutic agent against hemolytic streptococcus infection in mice.

Unlike the other great discoveries which we have described, the finding of a chemotherapeutic agent effective against streptococcus infections was made by the employee of an industrial firm interested in financial gain and in a Germany very different from that which nourished Virchow, Koch, and Ehrlich. The therapeutic agent which Domagk discovered was patented under the name of "prontosil" in 1932 but no notice of this patent was published until 3 years later. A few German clinicians were given the compound for testing in patients but they were not informed as to its nature. Their clinical reports did not appear until 1935. "The I. G. Farbenindustrie had apparently withheld knowledge of the therapeutic value of prontosil so that its chemists could have time to prepare and test a large number of chemically related compounds." (4)

The keenness of French chemists ruined the German effort to control the important discovery. The French workers concluded that the effective agent in the mysterious "prontosil" must be p-aminobenzene sulfonamide, or sulfanilamide for short. This proved to be the case. Since sulfanilamide was a compound known to chemists even in 1908, it could not be patented. The complete information was then given to the scientific world.

In England, Colebrook confirmed Domagk's animal experiments and was able to produce convincing evidence that the new chemotherapeutic agent was effective in man, something the Germans had failed to do. He showed that by the use of prontosil or with sulfanilamide the mortality from puerperal sepsis or childbed fever, the great hazard of childbearing, could be reduced from between 16.6 and 31.6 percent to 4.7 percent.

The story that follows is one of discovery of new compounds, modifications of the original ones. Sulfapyridine, sulfathiazole, sulfadiazine, and sulfamerazine now are names familiar to everyone. Administered to human beings ill with lobar pneumonia, sulfapyridine reduced the mortality of the disease from about 25 percent to 5 percent. All the tediously produced and costly pneumonia antisera were superseded over night. In certain other infectious disorders equally dramatic effects were observed. The results following the use of the sulfonamides have been truly revolutionary. These agents have proved useful not only in treatment but also have been found valuable in preventing the spread of certain types of infections such, for example, as cerebrospinal meningitis, which might otherwise have developed into epidemics.

Medical news last week vied with news of the days before invasion. Under the aspect of eternity, the medical news might even be more important than the military. WPB announced that the wonder drug penicillin, for three years practically a monopoly of the Army and Navy, was now being manufactured in such quantity that it can be issued to civilians. (Time, May 15, 1941, p. 61.)

Medical progress is still in the news and a chemotherapeutic agent even more wonderful than the sulfonamides has become available. People may look, but few see. No doubt many others before Alexander Fleming had looked at bacterial cultures accidentally contaminated with mold. But it remained for him to notice that the mold had cleared a wide, bacteria-free area between itself and the staphylococci on the plate. It was he who saw the potentialities of this observation. He soon found that a liquid in which this mold was grown, even when diluted 800 times, prevented the growth of staphylococci. Thus it was 2 or 3 times as strong in this respect as pure carbolic acid.

These events occurred in 1928. Eleven years passed before further progress took place. While penicillin was evidently a potent antibiotic, the problem of manufacturing it in adequate quantities seemed insuperable. Furthermore, the sulfonamides had been discovered in the meantime and seemed at first to make the need for the development of penicillin less important. At last, in 1938, Florey, Chain, and their associates in England approached the problem again, seeking evidence of the value of penicillin in experimental infections in mice and methods for its manufacture in quantity. They succeeded in making a highly concentrated preparation of penicillin which was effective experimentally and could be used in humans. But its production was difficult and cumbersome.

By this time, in order to coordinate scientific effort in the present war, there had been organized in this country under the Office of Scientific Research and Development (OSRD) and in collaboration with the National Research Council, means whereby the scientific facilities of the country and scientists in various fields could be marshalled. Dr. Florey came to the United States and, with the aid of a special committee of the National Research Council, a major attack on the problem of penicillin production was made. In this work the United States Department of Agriculture as well as a number of the large pharmaceutical houses played an important role. Without doubt the needs of war and the scientific collaboration which the war has brought about are responsible in large measure for the speed with which penicillin has been developed.

This new chemotherapeutic agent possesses many advantages as compared with the sulfonamides. These include its extraordinary speed of action, its effectiveness against organisms which the sulfonamides do not influence or which have become resistant to their action, and its lack of harmful effects. The speed with which penicillin acts, measured in hours rather than in days or weeks, is more dramatic in certain types of infection than even the most sanguine might have hoped for. A most unexpected finding is the value of penicillin in the treatment of early syphilis, a disease which is not influenced by the

sulfonamides. There is good reason to hope that certain other infections, hitherto unaffected by any measures, may be cured by penicillin. The lack of toxicity of penicillin is all the more appreciated because we have learned that the sulfonamides sometimes produce harmful effects which may even prove fatal.

MEDICAL SCIENCE AND THE WAR

During our own Civil War four times as many men died from disease as from the wounds of battle. During World War I the mortality from battle casualties for the first time exceeded the deaths from communicable diseases. This was brought about by a combination of factors such as camp sanitation, prophylactic vaccination, personal hygiene, the isolation of disease carriers, contacts and suspects, and the practice of vigorous delousing. Modern warfare, thanks to the advances which have been described and to others which must still be mentioned, should have a much better record in spite of the fact that it is far more widespread than ever before and in spite of the new lethal agents that have been devised.

At Pearl Harbor not a single patient with a gunshot wound of the abdomen who reached the operating table alive and in whom the visceral wounds could be repaired, subsequently died. This can be attributed largely to the sulfonamide that was used. There never has been such a record in military surgery before. Penicillin, no doubt, will make the record even better.

The management of shock is just as important in the handling of the wounded as the control of infection. Shock is the state of general collapse that follows any severe injury or wound. It is often fatal and to avoid death immediate treatment is necessary. This war has brought the development of dried blood plasma, still the most valuable agent, other than whole blood, for the treatment of shock. Such plasma can be transported easily and after addition of water can be given the wounded even on the battlefield. This procedure, as well as the present highly developed system of field and hospital care and the use of transportation for the wounded, represent steps of enormous value.

The chief medical problem of the war probably is malaria. This is because our troops must operate in the regions where the bulk of the 3,500,000 deaths from malaria recorded annually occur. Never before have millions of men engaged in tropical warfare and thus this great disease predator has an unsurpassed opportunity to exert its influence. The capture of Java deprived us of the chief source of quinine but fortunately atabrine, a drug synthesized by the Germans following the First World War, is equally good if not better than quinine. Thousands of men have been given small doses of atabrine regularly for many months to hold in check malarial infection which could other-

wise incapacitate them. Neither quinine nor atabrine, however, is an ideal antimalarial for neither will destroy certain stages of the parasite (sporozoites) or prevent mosquito-borne infection. Neither drug completely cures tertian malaria although atabrine appears to be excellent in preventing the development of the most dreaded type of malaria, the so-called malignant tertian. A coordinated effort is being made to find better antimalarials than quinine or atabrine. For these experimental studies 1 percent of the ducks in the United States are being used.

Control of malaria depends fundamentally on the prevention of bites by infected anopheline mosquitoes. Draining or filling mosquito breeding places, destroying the larvae there, screening buildings, and spraying insecticides are measures employed at Army base installations. A "mosquito bomb" has been developed which employs pressure from the inert gas freon to discharge an insecticide far more effectively than can be done with a flit-gun. The most outstanding advance in insect control during this war has been the discovery of the remarkable insecticidal properties of DDT, which stands for dichloro-diphenyl-trichlorethane. Its use prevented a serious epidemic of typhus in Naples just as our troops arrived there and it is proving of great importance in the control of malaria.

The war and modern transportation have made acute the problem of transmission of disease by insects. Yellow fever, like malaria, is transmitted by mosquitoes. Certain flies transport the trypanosome of African sleeping sickness. Bubonic plague is carried from rat to rat by the bites of fleas and from rats to man by the same insect. Lice transmit typhus and relapsing fever. These few examples indicate that insects carry viruses, bacteria, protozoa and spirochetes to man.

Thus, as Huff (5) has put it, "Long before man became air minded, some of the microbes were using insects for transportation." It is not difficult to imagine how, when this limited means of transportation is aided by man's mechanical wings, the transmission of disease and the possible development in this country of what we once considered exotic diseases may become a very serious problem. "The flea which carries bubonic plague and normally hops a distance of 3 to 5 inches may possibly hop from one continent to another. Ticks, which are among man's worst enemies, have been restricted in their range by poor powers of locomotion. Will they discover our wings and 'hitch-hike' a million times as far?" (5)

In 1938 Whitfield investigated the insects found inside aircraft. He collected 277 species of insects and these included 5 species of mosquitoes known to be capable of transmitting yellow fever and 5 species which can transmit malaria. There was also a specimen of tsetse fly which transmits African sleeping sickness, a bed bug, a flea, many horse flies, many species of house flies, cockroaches, and black

flies, and 10 species known to be vectors of 6 different animal diseases. Rats have also been found in aircraft. It has been shown that mosquitoes may survive journeys of over 9,500 miles lasting for 6½ days and that some of them though frozen on arrival have revived when they became warm again.

The danger lies not so much in infected insects biting several individuals and causing illness thereby, but in the possibility of their becoming established in the new region to which they have been transported. This occurred in Brazil and required much effort and expense to eradicate. The transportation of freight by aircraft will probably greatly facilitate the transfer of infected small animals, like rats.

Our own Public Health Service has been fully conscious of the possibilities of this mode of transmission of disease and measures had already been taken before the war to meet some of the problems which had been raised. Undoubtedly, however, with the rapid expansion of air transportation, vigilance will have to be keen if serious trouble is to be prevented.

Necessity has caused a new branch of medicine to develop to an unprecedented degree. The airplane of today functions better in the air than the man who flies it. The exploitation of all the possibilities of these extraordinary machines has been quite definitely hampered by the limitations of man's capacity for adjustment to unusual conditions. It has been the task of aviation medicine to find ways of adjustment to changes of barometric pressure, to reduction of air pressure, and to extraordinarily rapid changes in direction and acceleration. This has required an expansion of the study of physiology which will be valuable in many ways besides those related to flying.

It was learned in World War I that 90 percent of the accidents in the air were due to errors of the pilot and that in some squadrons 50 percent of the pilots were suffering from a neurosis which made them actually unfit for duty, though they continued to fly anyway. The problem has been enormously magnified in the present war.

Decreases in atmospheric pressure with increasing altitude are responsible for two of the major difficulties of the flier, namely the expansion of gases contained in the cavities, tissues, and fluids of his body and the effects of lack of oxygen or anoxia. Although the body is capable of making some adjustments to the effects of changes in barometric pressure, these cannot be made as quickly as our present machines are capable of rising.

One source of trouble is the expansion of intestinal gases. At 18,000 feet their volume is doubled as compared with that at sea level and at 33,700 feet it is quadrupled. With rapid rates of ascent these gases, instead of being eliminated, get caught in the intestinal loops and produce severe abdominal cramps. There is also the problem of the

expansion of nitrogen, which constitutes 78 percent of the air. This gas is dissolved in the body fluids in proportion to its partial pressure. When this pressure is reduced on ascending to a high altitude, if sufficient time is allowed the excess of dissolved nitrogen is brought by the blood to the lungs and is blown off. If ascent is very rapid, however, the gas is liberated before it reaches the lungs. Bubbles form in all the tissues with the result that the joints become stiff and sore, motion becomes impaired or is even totally inhibited (the "bends"), the skin itches and burns and giant hives may appear, and severe neuritic pain may develop owing to the large proportion of nitrogen which tends to accumulate in the fatty tissues of the nervous system. Bubbles forming in the brain may produce convulsions, paralysis, and even death. One of the most distressing and dangerous complications is "the chokes," in which a burning sensation develops under the breast bone, followed by stabbing pain and progressive inability to breathe normally without coughing. Under combat conditions, as for example in interceptor planes which must take off at a moment's notice, there is often insufficient time for adequate desaturation.

The effects of lack of oxygen are insidious and not easily detected. Up to 10,000 feet the flier notices nothing except perhaps some increase in the rate and depth of respiration. A vague feeling of uneasiness may appear, the breathing becomes deeper and the pulse more rapid. Between 15,000 and 18,000 feet if he stays there for more than a couple of hours the flier is likely to experience severe headache, nausea and vomiting. Even with shorter exposures at this altitude, certain important mental changes occur. He may become rather depressed, sleepy and tired or elated, hilarious and aggressive, even pugnacious. He may not remember what his course is supposed to be but he does not care. There is a marked resemblance to alcoholic intoxication. "Time sense is impaired and hours seem like minutes or vice versa. If he must perform any calculations, he finds that simple arithmetic is too much for him and his trembling pencil makes distorted figures on the paper. As he climbs above 20,000 feet his handwriting becomes a meaningless scrawl. His field of vision is constricted, the sky looks dark and the noise of the engine may be nearly inaudible. He is eventually unable to move a muscle and, at about 25,000 feet he passes into coma." (6) These ill effects can be met in large measure by the inhalation of oxygen. Regulations make its use compulsory above 10,000 feet. Unfortunately, however, some pilots in spite of rules see no reason for taking oxygen as long as they feel all right. Too many fail to realize that probably the most dangerous feature of oxygen want is the insidiousness of its approach.

The availability of oxygen through tanks is only one factor. At 40,000 feet, where planes are now flying, adequate oxygenation of the

blood is maintained with difficulty owing to the lowered air pressure. Adequate pressure cabins or pressure tubes are required, but these are not yet practical or available for routine use.

Everyone now is familiar with the need for equalization of atmospheric pressure on both sides of the ear drum. It is relatively easy to make this adjustment on rising to higher altitudes but the reverse is not accomplished as readily. The commercial airlines consequently do not permit descent at a rate faster than 300 feet per minute. The dive-bomber, however, may descend one hundred times as fast. The pilot of such a plane is hard pressed to ventilate his middle ear.

Speed of motion does not in itself demand physiologic adjustment, but acceleration, that is, changes in rate of direction of motion, has profound effects upon the body. Imagine, for example, the effects of centrifugal forces on a pilot as he pulls up from a long straight dive. His "jaw sags open, there is a dragging sensation on his chest and abdomen as the internal organs are pulled downward, the limbs become so 'heavy' that it is impossible to move them; the legs feel tight and congested as indeed they are, and vision becomes blurred. If the stress is continued vision is lost completely ('blackout') and later consciousness," (6) is also lost. The effects are due in large part to the displacement of blood from the head to the abdomen and legs.

These are only some of the problems which confront the medical scientists who have been engaged in the study of aviation medicine. The selection of men most suitable for aviation, the development of maneuvers to meet the extraordinary acrobatics required in air warfare, the invention of equipment which is at the same time efficient and practical, are included in their tasks. Only when the war has been won and some of the details are no longer military secrets, will we know in full to what extent these problems have been met.

Approximately 30 percent of the casualties in battle zones are psychiatric in nature. In the management of such casualties early and correct treatment is of the utmost importance if lasting neuroses are to be avoided. Rest, supported if necessary by sedatives, good food, quiet and reassurance before the casualty has been removed too far from the battle zone have served to make it possible for 70 to 80 percent of the combatants to return to duty. Among the Australian forces at Tobruk there were 207 cases of neuroses. These comprised for the main part states of anxiety and fear. With early treatment 60 percent of the men were restored, fit for frontline service, whereas only 12 percent had to be returned to Australia as permanently unfit.

In many other ways is medical science contributing to the war effort. Tank warfare, for example, has its own problems. Chemical warfare has others, both from the viewpoint of attack and that of protection. Malaria is only one of the plagues endangering our troops

in the Tropics. Limitations in the supply of blood plasma have led to a search for blood substitutes and this has already yielded many valuable results far outside the limits of the original problem. Food is one of the most important factors in war. This is not only a matter of vitamins but of energy-supplying substances and minerals as well. Insufficiency leads to fatigue, lessened industrial efficiency, lowered morale, and finally to unrest, riot, and revolution. An ample reserve of fat and oil is important because these contain the largest amount of potential energy of any of the foods. We have none too ample a supply. Scurvy would have been a serious problem in the British Isles had it not been possible to furnish synthetic ascorbic acid in the place of the far bulkier citrus fruits for the shipments of which tonnage was lacking. We must meet food deficiencies in countries now being occupied and must stamp out the infectious diseases which always become rampant under such conditions and plague not only the immediate region but by their spread endanger the whole world.

When the full story of the role of science in the war effort is told, it will appear as an example of "teamwork and cooperation in coordinating scientific research and in applying existing scientific knowledge to the solution of the technical problems paramount in war," of which we will all be proud. This coordination has been organized by the Office of Scientific Research and Development under the leadership of Dr. Vannevar Bush. The above quotation is taken from a letter addressed by President Franklin D. Roosevelt to Dr. Bush (*Science*, vol. 100, p. 542, (Dec. 15) 1944). The public is not aware of the ramifications of this work because for reasons of security much of it has necessarily had to be conducted in secrecy. "Its tangible results can be found in the communiques coming from the battlefronts all over the world" (*loc. cit.*). Thousands of scientists in universities and in private industry are engaged in this work. The development of penicillin and the attack on malaria are only two examples of the results of this coordinated effort in the medical field. This work, valuable in war, will be just as important in peace for "the annual deaths in this country from one or two diseases alone are far in excess of the total number of lives lost by us in battle during the war" (*loc. cit.*).

THE SUM TOTAL

One way of measuring the results of advancements in medical science is the statistical. How long did the average newborn child live in former times, and what is its life expectancy today? What is the life expectancy at other ages? How much has infant mortality been reduced?

During the industrial revolution in England when mothers began working in factories and were forced to leave their infants with wet

nurses or to be bottle fed with inadequate feeding formulas, the infant death rate was frightful. In Dublin, during the period 1775-1796, the mortality rate at the Foundling Hospital was 99.6 percent (4). At the beginning of the nineteenth century it was estimated that about one-quarter of all children died before they reached 2 years of age. In London, during the period 1790 to 1805, 41.3 percent of all children died before reaching the age of 5 years. The great historian Gibbon was the sole survivor of 7 children. Even as late as 1870, when proper mortality records first began to be kept in New York City, more than 38 percent of infants born alive died before the age of 1 year. Infant mortality started to make a sharp decline about 1870. Today it is less than one-tenth of the figure at that time.

A comparison has been made of life expectancy. Tables of life expectancy were made in Ancient Rome (4). These showed that 2,000 years ago the expectation of life at birth was about 22 years. In Massachusetts and New Hampshire in 1789 the expectation of life at birth was 28.2 years. In 1855 the figure had risen to 39.8. In 1901 it was 49 years. Today it is well over 60 years.

Such statistics indicate only deaths and fail to reveal the unhappiness and the economic loss produced by illness. These are difficult to record in numbers.

The expectancy of life in infants, children, and young adults has increased greatly and even the middle-aged person can expect today a longer life than could his ancestors of similar age. The data are favorable up to the age of 50, but after this age there is comparatively little difference between the Roman citizen's expectations and that of the man of 55 or more today. This is a very significant fact because it points the way to the problems of the future. The leading listed causes of death in the United States in 1900 were influenza, pneumonia, bronchitis, tuberculosis, diarrhea, and heart disease, in the order named. These conditions accounted for almost 7 deaths per 1,000 population and of this number heart disease took about 1. In 1939, approximately the same number of deaths were caused by the following, in the order named: heart disease, cancer, brain hemorrhage, kidney disease, and lastly influenza, pneumonia, bronchitis, and tuberculosis. Heart disease accounted for almost 3 of the 7 deaths, and cancer averaged more than 1, whereas in 1900 a number of other diseases took precedence over it.

The true significance of these facts can only be gathered by consideration of the average age of our population, because heart disease and cancer become much more frequent as age advances. The proportion of people over 65 years of age has almost doubled since 1900. This is due to the fact that the greatest advances in medical science have been made in the attack against the diseases of childhood and of young adults. These are the age periods in which the control of

infection, the attack on contagious diseases, on tuberculosis, and on typhoid fever, and the advances in nutrition have had their greatest effect. Advances in the treatment of pneumonia and diabetes will influence all ages. In comparison with the advances in other fields, progress in the fields of cancer and heart disease including that produced by rheumatic fever, high blood pressure and hardening of the arteries has been insignificant. This is why these conditions seem to be more prevalent. Kidney disease, leukemia, various forms of rheumatism, many virus infections, and many more diseases still stalk our path. We live, so to speak, to die of other things. We escape diphtheria in childhood but other unconquered enemies menace our later years.

THE MEDICINE OF TOMORROW

These then are some of the problems of medicine today. We have not touched upon the advances in the large and important field of industrial medicine nor on the problems there which remain to be answered. There has been no mention of endocrinology—the branch of science which deals with hormones. Remarkable discoveries have been made and much remains to be learned. We must bear in mind that the “wonder drugs” that have been discovered do not control all infections. There are many types of infection over which they have no influence; for example, most of the infections caused by viruses—infantile paralysis, rabies, sleeping sickness, influenza, parrot fever, yellow fever, and the common cold.

Then again the problems of convalescence are rising in importance. When most of our efforts had to be directed toward the control of infection, we were in the main content to let convalescence take its own gradual course. Today, with the high premium on manpower that exists, and with the greatly improved methods for the management of infections, a legitimate impatience with the slowness of repair has arisen. This problem is pointed up by the needs of the Armed Forces, where a man is not regarded as well until he is ready to enter the firing line again. A reduction of even 33 percent in the duration of convalescence would obviously be an important gain from a military standpoint, to say nothing of civilian life, where the industrial worker's time is likewise precious. Physical therapy, occupational therapy, re-education and rehabilitation take important places in the problems of convalescence. These problems are being attacked at present under the direction of the National Research Council. Our own laboratories, at their request, are at present engaged in the investigation of certain phases of this work.

Psychiatry has, relatively speaking, been a neglected field of medicine. Within the field of psychiatry must be included not only the late manifestations of mental disease which crowd our mental in-

stitutions and which, incidentally, represent an enormous and largely avoidable expense to the State, but also the much wider field of less obvious mental disorder which exists all about us and which profoundly influences not only the affected individual's well-being but that of his associates and of society in general.

We are only beginning to appreciate to what extent emotional and other psychological factors find expression in somatic complaints. Relatively few physicians have as yet been able to break the arbitrary barrier we have all been inclined to set up between mind and body and too few are prepared to consider the patient as a single unit needing attention as such.

The medicine of tomorrow envisages the successful solution of these problems. With a wider appreciation of the value of research and increasing public support for such work, as well as with the lessons being learned under the pressure of war regarding the value of co-ordinated effort, there is every reason to believe that the hope for far greater success in the attack on disease than we have achieved so far, is not Utopian.

The advances in medical science which have been described, and many other important contributions to our knowledge which have not been mentioned because of lack of time, are of comparatively little value if the majority of the people do not profit by them. Medical knowledge has progressed rapidly, but the application of these advances has lagged far behind. Witness the matter of tuberculosis. With a systematic, concerted effort, this disease could be stamped out. By means now available, X-ray films could be taken of our entire population at comparatively little expense. Hidden carriers of tuberculosis who are responsible for its continued spread could be detected and by simple measures these carriers could be rendered harmless. To bring this about, the public itself must be interested and must force upon its officials a demand for the adoption of the necessary steps. All too often pressure is brought on public officers only by those short-sighted individuals whose chief interest is in limiting public expenditures rather than by those who understand the value of efficient, far-sighted, and advantageous use of public funds.

With proper measures, syphilis and gonorrhea can also be completely eradicated. The Scandinavian countries a number of years ago made these diseases medical curiosities instead of public menaces. Thanks to the leadership of the Public Health Service we are beginning to attack the problem of venereal diseases intelligently.

The importance of sanitation is common knowledge. But, strangely, we tolerate abuses all about us. Management of such matters is sometimes left in whole or in part to persons who may be indifferent or uninformed and who have no special training in the field of public

health. Restaurants we frequent are allowed to be conducted in ways which offer opportunities for the spread of disease. Kitchen help in various institutions are employed without examination as to the likelihood of their transmitting disease, without instruction as to their public responsibilities, or supervision as to their cleanliness. Unpasteurized milk is sold in certain communities which has been taken from cows inadequately inspected. This community is no exception to these criticisms. We wait for a serious epidemic to break out before giving thought to such matters. That is a very heavy price to pay.

In yet another important phase is the citizen failing to profit fully from the advances in medical science. Medicine has been so transformed in the past several decades that the examination of the individual is no longer a matter of the pulse, the temperature, and the appearance of the tongue. The more precise methods of the present day require X-ray equipment and laboratory facilities, some of which are complex and expensive. These in many instances are impossible to apply in the home or even in the average office. Thus we have seen the growth of clinics and specialists. The hospital has become the doctor's workshop; that is, the place where he has, or should have, at his disposal every new means for diagnosis and for treatment which science has devised.

These developments have led to a great increase in the cost of medical care. An adequate examination is more costly than the average person is prepared to pay if he makes no special provisions for such expenses. Health is still regarded as something which does not compare in the family budget with food, clothing, and rent; yet every thinking person realizes that in the last analysis provision for health is a good investment in ensuring the more obvious and seemingly more pressing matters of bread and butter. Means must be worked out whereby the whole community, the middle man as well as the rich and the poor, has access to the best in medical care. These means must not be stereotyped or routinized for good medicine cannot be practiced in that way. The doctor-patient relationship and the right of the patient to the free choice of his physician must be preserved. That is a precious heritage without which it would be difficult to apply the advances of science to the full profit of the individual. We are confronted with a serious and complex economic problem which must be solved. Many students of the subject believe that the solution can be found by making improvements in the present methods of medical care rather than by extreme measures involving so-called "socialization" of medicine.

The well-trained physician expects to practice his profession with the full utilization of modern knowledge and methods, even though these be costly. He has a right to expect this and a duty to inform his patient of the facilities which should be available to him. The

patient, on his part, should expect of his doctor an appreciation of the advances which are being made and an understanding of their application—or at least the physician must know, if the problem is somewhat complicated, how and where up-to-date methods and information can be obtained; for we have long passed the time when any single physician could apply and manage all the tools of medical science. It is not sufficient to have penicillin. Unless a diagnosis is made correctly and treatment initiated promptly, even this remarkable drug will fail.

The establishment of a 4-year medical school in your midst should aid in the attainment of many of these goals. A good medical school is much more than a trade school which offers to a certain number of young men and women the opportunity of learning “the what” and “the how” as they are known today. By providing facilities for and encouraging research it brings to your midst and fosters in your medical community a spirit of inquiry, a search for newer knowledge, an awareness of, as well as the means for, evaluating advances in medical science wherever they may have been discovered. Such a spirit of inquiry must be inculcated in the medical student, for the best-trained doctor and the most effective is the one who is able to think, to seek out, to evaluate, and to apply.

A good medical school must also be the center for postgraduate medical education. The physician who does not remain a student all his life soon falls behind. His needs are not met by occasional attendance at meetings. It is only by weekly and even daily conferences and discussions with his fellows and with experts in various special fields, that he can keep up. These are things that your medical school should do for you and your physician.

* * * * *

Medicine has changed from an art based on a little knowledge, a greater or lesser amount of “common sense,” and a certain degree of nonsense and even of charlatanism, to become more and more of an exact science. This progress has brought with it certain problems of practical application but it also offers opportunities for benefiting mankind which are truly great and must be exploited. The advances in medicine have opened up as many problems as they have answered. To fathom the goings-on in a mechanism so complex as the human body, to determine the chemical reactions which take place in the myriads of cells of microscopic size and of many different types which make up this organism, to learn the workings of the mind and its relation to the organism as a whole, to discover the reasons why these different structures sometimes fail to function normally, and to find means whereby they can be restored to their normal activities, is a

stupendous task the size of which only those who are familiar with the knowledge already gained can begin to appreciate. Yet the progress which has been achieved in this fascinating search makes one await with the keenest interest the discoveries of tomorrow.

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TECHNOLOGY AND MEDICINE¹

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Hardly any other field of science is as misunderstood by the general public as that of medical research. Excessive dramatization is partly responsible for several popular misconceptions. Most common of these ideas is that the predominant number of advances in medicine begin with a man, sitting at a sick bed, utterly shaken by the effects of an incurable disease. Suddenly he has a new idea. He makes a few experiments, preferably on himself, which are successful. At first, no one believes in his work, but finally he is recognized and cures thousands of people.

Medical research does not follow such a course. Nor does a medical research center suddenly flourish into full bloom after a chance meeting has brought together a physician, a chemist, a physicist, and an organizer who become united in their humanitarian collaboration by a burning desire to relieve the sufferings of humanity.

For the past 20 or 30 years chemistry has played an important role in medicine, whereas the participation of physics has been relatively limited. This condition is easily understandable. With the exploration of the chemical composition of, and processes occurring within, the body, a number of specifically acting compounds were found which could be used therapeutically. Not so in physics. The physical phenomena and forms of energy—particularly those employed in physical medicine—are mostly nonspecific, at least in the way in which they were used in the past. Another reason for the relatively small influence of physical sciences in medicine is simply that physics is too difficult. The physical phenomena in biology and medicine are for the most part so complicated that they have not yet been explored. The whole arsenal of physical research, from quantum theory to the technique of instruments of the highest sensitivity, is needed to investigate these problems. Without these powerful tools, any research in the biophysical field was formerly rather hopeless. ⁵

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Already we have reached the point where a change of decided importance can be observed. The theoretical and technical means of this research are now available. The interest in, and therefore the number of articles and books about, subjects in physical medicine, biophysics, and medical physics has considerably increased of late. The war has stimulated important research in physiology as related to physical phenomena. There is much evidence of the desire to make the results of recent physical and technological investigations available for the service of biology, medicine, or public health. This tendency is manifested in the fields of electronics and instrumentation, in transportation engineering and air conditioning, in nuclear physics and, quite significantly, theoretical physics.

The introduction of physical and technological research into the medical field is very promising. Formerly, medicine had been developed on a highly empirical basis. Medical men were concerned merely with the over-all effects produced; a living organism such as a guinea pig would be treated in a specified manner, and the gross results of the treatment would be observed. The newer approach involves a quantitative study of the effects of the various physical phenomena acting upon the living organism and investigates step by step the results of these actions. Even though accurate physical measurements cannot yet be made on each and every aspect of the phenomena, the value of the approach is beyond question.

To illustrate this type of research, assume that we wish to study the medical effect of an X-ray treatment, applied to a given location of a tumor at a certain depth in the body. The treatment may be given under a great variety of conditions, using different X-ray generators, tubes, voltages, currents, filters, and distances between the generator and the subject. The biological results of such a treatment will be different in each case. But when we know enough about the absorption and scattering of X-rays in tissues and the effect of wave lengths and other physical magnitudes, we shall be able to predict the dose distribution in the body. Experimental results then become comparable, and the biological and medical results can be correlated with the physical phenomena causing them. At the same time, the number of variables involved diminishes greatly as will the number of opinions and contradictory reports so frequently encountered in medical literature.

The result of any kind of therapy is to be measured by the clinical success and the cure of the disease, of course. The process of healing a disease is, however, a consequence of a given treatment in addition to a great number of physiological and psychological processes. So long as consideration is restricted merely to the treatment and the cure, one does not know whether the patient got better because of, or

in spite of, the treatment. In other words, the mere observation of the clinical end result is unsatisfactory because it is incomplete. Only that type of medical research which investigates the action of the treatment step by step will lead to the finding of natural laws which will always be valid and which, in the hands of the physician, will be a valuable guide to him.

This type of research also indicates how medical instruments should be fashioned so that better results may be obtained. For example, research on high-voltage X-rays has shown that it is possible to obtain an increase in X-ray energy in the depth of the body in such a way that the surface layers through which the beam passes are relatively little affected. This knowledge is of greatest importance in the treatment of deep-seated tumors, and the development and production of appropriate equipment for clinical use follows as a logical consequence of such research. This single example is sufficient to show that physical and technological research may brilliantly complement clinical observation in furnishing the guiding principles for supplying medical men with new equipment.

DIAGNOSTIC APPLICATIONS

A great need for research and development may be anticipated in the field of physical diagnostic methods and instruments, and here again technological developments are able to make substantial contributions to medicine. One of the most commonly used instruments in the doctor's office, the stethoscope, belongs in the category of such physical diagnostic tools, and its development illustrates the benefits which modern technology can bring to the medical sciences.

When the stethoscope was first introduced into practical use in 1819 by René Laënnec, it consisted of a rigid hollow tube with enlarged end pieces. In this form it was used for a long time until the stethoscope with flexible tubing and a membrane at one end was developed. Mechanical resonance is employed to some extent in the flexible-tubing stethoscope and provides some amplification over a narrow but useful frequency band. Today, through the use of a microphone and a suitable electronic amplifier, the electronic stethoscope makes possible the reproduction of the sounds of heartbeats for large audiences. At the same time, the instrument is able to record all aspects of systolic and diastolic contractions or, using filters, to select for special study any range of the frequency components of heartbeats. At present, the electronic stethoscope is used primarily for research, but there are other electronic instruments which have been adopted in standard routine examinations in medical practice.

Research on physical diagnostic methods and the development of instruments required for diagnosis are particularly promising at pres-

ent through the use of electronic means. The complete lack of inertia in electronic equipment (at least so far as concerns the biological process to be measured), the ability to amplify, and the negligible amount of input power required to control electronic devices are, in part, reasons for the general anticipation of such a development. But biological considerations also contribute good reasons for the adoption of electronic equipment. Of these reasons, one of the foremost is that minute voltages, called action potentials, are produced within the body as a result of biological activity of the heart, brain, or nerves, for example. The amplification, detection, and analysis of these action potentials has opened up new fields of diagnosis which have reached their most advanced developments in the fields of electrocardiography and electroencephalography. Moreover, it has been found that the electrical characteristics of the skin may be used for diagnostic purposes, and here again electronic equipment is called upon to play its important role.

In electrocardiography the action potentials generated in the body as the result of the beating of the heart are obtained from electrodes placed on the arms, legs, or chest of the patient. These minute voltages are then amplified and recorded. A deviation of the recorded curves from the normal pattern indicates a pathological alteration of the heart activity. Since the patterns for different diseases are known, a reliable differential diagnosis is usually possible. It has also been proposed to use these action potentials for therapeutic purposes, as, for example, resuscitation or the treatment of cardiovascular diseases. Pick-up electrodes, from which the action potentials are obtained, are attached to the patient. After suitable amplification these potentials are reapplied to the patient by means of another pair of electrodes. By designing the amplifier for proper phase shift or delay of signals, it may be possible to stimulate the activity of the heart in its own rhythm. In this technique the heart is used as a self-excited oscillator. As yet, little is known about the results obtained with this method.

The electrical activity of the brain is recorded by means of the electroencephalograph, which makes possible the diagnosis of certain mental disorders by means of electrical potential measurements on the scalp. The principle of the electroencephalograph is similar to that of the electrocardiograph. The interpretation of the curves, which are naturally much more complex than those of the electrocardiograph, is, however, sometimes difficult. Considering the very complicated processes of the brain activity, we would expect this, but the difficulty is a particular challenge to obtain more and better information by the use of improved equipment. With this method it is now possible to determine the location of a brain tumor (sometimes very important in brain surgery), and it may become feasible to

localize or coordinate certain parts of the brain with some mental or physical anomalies. A considerable increase in the sensitivity of the instruments used in electroencephalography is not possible, however. The magnitude of brain action potentials is close to the noise level which it is impossible to overcome.

It is to be expected that further research on electric nerve action potentials in connection with other organs, glands, and so on, will evolve diagnostic methods which are perhaps of even greater importance in general medicine or in psychiatry than the ones we already have. The difficulties are great; what we measure is largely a superimposition of many different electrical signals. Sometimes the development of special experimental techniques is required to eliminate those signals which are not desired and to record undistorted the signals characteristic of the process under study. One difficulty here is the lack of a proper explanation of the fundamental process of propagation of nerve action potentials. The velocity with which an impulse travels along a nerve is of the order of one meter a second. This velocity is too fast for propagation to be achieved by purely chemical means; it is too slow to be the result of a purely electrical phenomenon.

The problem of physical diagnosis is frequently that of getting some information about processes going on inside the body from measurements on the body surface. Besides mechanical, thermal, or optical properties of the skin, its electrical properties can also be used diagnostically. From simple electrical resistance measurements of the skin one can get indications of the activity of the sympathetic nervous system and of emotional reactions of the person under observation. An instrument used for this purpose is known in medicine as a psycho-galvanic reflex meter and has attained wide publicity as the lie detector. It is very likely that this instrument, in the hands of an experienced psychologist, can uncover the deeper cause of many diseases and, perhaps, can open up a new physical experimental approach to psychological and neurological studies which, in the past, have been based solely upon theory.

THERAPEUTIC APPLICATIONS

Many persons also expect the field of physical therapy to show a development as rapid as that which has taken place in physical diagnosis. The situation with respect to the search for physical means of healing and curing is, however, somewhat different from that of diagnosis. In his popular book about medicine² Dr. Carl Binger characterizes research in therapeutics with the words,

Like happiness, a cure is seldom found by searching for it. Some cures are the logical outgrowth of deep scientific understanding, others are stumbled upon by

² The Doctor's Job, p. 149. W. W. Norton & Co., Inc., New York, 1945.

accident and still others have grown out of the ancient experience and wisdom of the race.

Physical medicine, in particular, is the outgrowth of experience. Apparently heat and cold, air and water, and the beneficial influence of the sun's radiation have been used to fight diseases since the earliest times of humanity. The powerful effect of radiation therapy is known to everyone who has used this treatment in too large dosages on the beach; painful sunburn is the vehement reaction of the body. On the other hand, lack of the sun's radiation can cause severe diseases, since the formation of important compounds in the skin is due to photosynthetic processes and requires the presence of radiation of the appropriate wave length.

The wave lengths of light which are of greatest importance in medicine are located in the ultraviolet portion of the spectrum. In general, three different ranges of ultraviolet radiation may be distinguished. The range of from 315 to 400 millimicrons has the power to penetrate the skin to an appreciable extent and is used in the treatment of some diseases, for instance, lupus. A second range of ultraviolet radiation, between 280 and 315 millimicrons, produces erythema of the human skin and is applied in the treatment of rachitis (rickets). The range of wave lengths shorter than 280 millimicrons has a particular germicidal effect. The primary effect of ultraviolet rays on cells or on proteins is still a difficult problem, especially since it is expected that the energy of a single photon of the radiation must have some relation to the binding energies within the structure of proteins.

Such specific effects are not to be expected in the infrared part of the spectrum. The effect of infrared treatment consists more of superficial heat, which may increase the flow of blood through the capillaries, relax muscle spasms, or produce locally increased metabolism. Frequently one finds the opinion expressed that infrared rays are able to penetrate into the depths of the body, but this is not so. Particularly those lamps used in infrared therapy which operate at low-color temperature (room heaters, for example) produce a radiation of which not more than a fraction of 1 percent enters the skin. The wave lengths shorter than 0.7 micron are absorbed by oxyhemoglobin, those longer than 1.4 microns by the water content of the tissue. Of course, this does not mean that infrared treatments are ineffective but rather that beneficial effects occur only in certain regions of the body.

If heat is to be applied into the deeper regions of the body, the techniques of diathermy and short-wave diathermy are more appropriate. Short-wave dielectric and induction heating have been used in medicine for more than a decade and have been employed by industry on a large scale for only a few years. Industrial research

in this field has recently been so successful, however, that its results can now be used for medical applications. The development of ultra-high-frequency equipment during the war will enable us to use electromagnetic waves medically in the range between very short radio waves and infrared waves. Theoretical considerations and actual measurements made on short-wave radiation fields show that, at least to some extent, it is certainly feasible to localize the effects of electromagnetic waves to certain regions inside the body by focusing the waves on the desired area or organ.

Unlike direct-current or low-frequency electric impulses, high-frequency voltages and currents do not produce electric shocks. At radio frequencies, several amperes can be sent through the body without any sensation other than that of heat. But also direct current, direct-current pulses, and low frequencies are used in medicine. Recent research in shock therapy and also in the promising field of electro-narcosis demonstrates the possibility of using electrical power of low frequency and various wave forms for specific purposes.

Among the great number of physical agents which are actually or potentially important in medicine, that of climatological environment is very interesting but may be rather problematic in its influence. Different authors report that some diseases, like arthritis and rheumatism, and certain psychological and physiological conditions depend upon the weather. Many people are affected by a change of atmospheric conditions, as, for instance, the arrival of a thunderstorm or a snowstorm, and such effects can be very pronounced, depending upon the geographic location. Since temperature, humidity, and barometric pressure do not appear to be involved in this effect, it has been claimed that the electrical condition of the atmosphere is the important factor. Russian workers report interesting progress in this field, but it seems that additional research is needed to reach definite conclusions. Medically important discoveries may result from further work in this field.

It has been said that physical therapy is a purely psychological treatment. Considering the decisive importance of psychology in medicine, no other statement could be of higher praise to physical therapy. The important question is only whether the effect of treatment with physical agents acts first in the imagination of the patient and from there acts upon his body or whether a physical or chemical change in the organism can be proven to be a direct consequence of the physical agent. We know today that both effects exist, but we do not know enough about the individual factors and how they interact. Fortunately, the physical and biophysical part of this complicated process is accessible to experimentation and exact measurement, and we may expect much progress from research in this field.

EDUCATION

In the future, the complexity of the physical phenomena involved in scientifically oriented investigations in physical medicine will require the services of trained physicists. Many hospitals have already recognized this fact and have added physicists to their staffs. Some have installed biophysical laboratories, analogous to the biochemical laboratories, which have long since proved their value. The tasks of a physicist in such a position are numerous. Besides his own research, often in collaboration with his medical colleagues, he works out plans for treatment in special cases (e. g., deep therapy); he develops physical methods for special diagnostic and therapeutic applications; he keeps the medical staff informed about progress in physical research; he teaches (particularly in medical schools) advanced and specialized courses; and he advises the medical research workers whenever they need physical methods and instruments in their own research. Inquiries for such physicists have already been received from hospitals, and the Institute has in operation plans for the training of physicists for the medical field. The training of physicists and engineers in this field will also be of interest to a number of industries, in particular those concerned with medical instrumentation. The anticipated expansion of this branch will require specialists, trained engineers, physicists, and biologists to an extent which perhaps may be comparable to the man-power requirements of the chemical pharmaceutical industries.

To establish an efficient liaison between physics and medicine it is not merely sufficient for the physicist to know more about medicine and biology. It is also necessary for the physician to apply the physical way of thinking to these problems and to acquire some knowledge of the available physical technological methods. The writer has repeatedly found that the physician, thinking in biological rather than physical terms, does not always appreciate the necessity of an objective physical dosimetric measurement. In short-wave diathermy, for instance, the subjective feeling of heat is frequently used as a criterion for dosage of the treatment and has been defended as "biological dosimetry," which was considered superior to "mechanistic physical dosimetry." It is obvious that such a biological dosimetry contains two unknown variables: the physical field intensity and the physiological sensitivity of the patient. Two treatments on patients of different sensitivities can give entirely different results, although both patients indicate the same biological dose. A better training of the physician in physics (either premedical or postgraduate) and an additional training in instrumentation for the specialist in physical medicine are necessary not only for the physical quantitative approach

but also for a successful collaboration between physics and medicine.

The need for such a training has been recognized by the Baruch committee on physical medicine which has recently granted funds for the equipment of a physical medical laboratory to teach physicians the physical technological methods which are or can be applied in medicine and to develop and investigate such methods and instruments as may be most promising. This project is already in operation, but at the present time only a very limited number of applicants can be trained. The program offers a great opportunity for an intensive collaboration of physician and physicist from which may be expected new and better applications of physics and technology in medicine.

NATIONAL RESPONSIBILITY FOR RESEARCH¹

BY J. E. GRAF

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If any common ground for international thinking has emerged from the wide conflict just ended, it is that the world is looking forward to a higher level of well-being for all. Leaders both in Britain and in this country have given expression to such intentions, and the hopes of most peoples are in complete agreement. As we survey the colossal destruction of the war in human, scientific, cultural, and material resources, it is clear that the attainment of these hopes is a major challenge to the human race.

Science received world-wide recognition during and in the period following the First World War. King Albert of the Belgians advanced science on a national basis by subsidizing research laboratories in universities. Industrial research grew rapidly. Even the man in the street became aware of the importance of science and invention, for articles on important scientific and technological advances appeared in the daily press. This development was stimulated by the appointment of science writers by several metropolitan newspapers. The intelligent and fair approach of these writers to their subject did much to bridge the gulf which had hitherto separated the scientific from the nonscientific.

In 1938 there was published by the National Resources Planning Board under the title "Research, a National Resource," a thorough study of the relation of the Federal Government to research in the United States. In pointing out that research is a national resource, it directed attention to the obvious need for the development of that resource. In this admirable study an analysis was made of the amounts expended by agencies of the Federal Government and of the various fields covered. It included as well a discussion of restrictions on the use of Federal funds for research, including suggestions for improvement, many of which have since received favorable mention both in England and in the Bush report in this country. The section on

¹Address of the retiring president of the Washington Academy of Sciences, delivered before the Academy on the evening of February 21, 1946. Reprinted by permission from the *Journal of the Washington Academy of Sciences*, vol. 36, No. 4, April 15, 1946.

research in American universities and colleges pointed out the great use of these organizations in training research men and in conducting basic research, a field in which universities excel, for they are largely free from the responsibility for solving specific problems. The summary of findings and recommendations presented many suggestions which recent studies have shown to be essential to the increase of research both nationally and internationally.

The popularization of science was well under way at the time of the Second World War. General public interest in science was advanced further by the Germans in their oft-repeated mention of secret weapons. During their impressive early successes, these threats reached every ear—as indeed they were planned to do. The growth of allied superiority in the development of new devices both for offense and defense was given equal publicity. A parade of new and improved weapons culminating in the proximity fuse and the atomic bomb, left with the general public the fixed idea that success in warfare was dependent more on skilled scientists than on the millions of bayonets once boasted by a late dictator.

While the war was still in progress and the outcome by no means certain, the role of science in the postwar world was the subject of active discussion in Britain. This was a logical trend, for Britain is no stranger to state-supported science. In the several councils for agricultural, medical, and industrial research, in various governmental research laboratories, and in grants to universities for facilitating fundamental research, there exists a broad base for state-supported science. Beyond this, there was a steady drift toward the full utilization of science in the war effort, an urge that came from scientists and government alike. Late in 1941 a meeting of prominent scientists and representatives of the war science committees was called by officers of the Royal Society. The principal subjects for discussion were postwar problems, including those of the immediate postwar period as well as those relating to the welfare of the peoples of the Empire. Even in these preliminary discussions it was stressed that while a little coordination may be necessary to guide research into profitable paths and guard against useless duplication, science must be kept free from close supervision which could develop into regimentation.

This trend toward planning for postwar research continued in succeeding years. There were people who still insisted that the development of science should be left to individual initiative, but they were fighting a losing battle against those who said that science should be centrally organized and that research in many fields must be expanded by government action. The phenomenal success of science in warfare, which by this time was turning the tide of battle, was quoted as a sign that freedom from want could be insured only through a full utiliza-

tion of science. It was pointed out that this greater, state-supported research could be directed by committees representing government, scientific societies, and research departments. The development of both pure and applied science as rapidly as possible was recommended—pure science because it is the source of ultimate technological advance, applied science because it translates the advances of pure science into security and public welfare. As pointed out in statements from Nuffield College, however, the distinction between pure and applied science can be overstressed, since both methods can be, and often are, used simultaneously in solving problems.

There were also differences of opinion regarding the relations of science to politics. While the decline of German science since the ascendancy of the Nazi Party in 1933 was presented as proof that science cannot under all conditions remain free of the effects of political change, Sir Henry Dale was a powerful spokesman for those who wished to keep science free of politics. "I see danger," he said, "if the name of science or the very cause of its freedom should become involved as a battle cry in a campaign on behalf of any political system, whether its opponents would describe it as revolutionary or reactionary. If science were thus to be used as a weapon of political pressure, it would be impossible to protect science itself from the pressure of sectional politics." In general the fear that a state-supported science would become involved in politics, or would lose its freedom of action, has declined in Britain. A powerful organization of scientists, and the ability to present promptly all controversial opinions to a court consisting of an informed and unprejudiced public opinion, are weapons that would work against any action, whether by government or by pressure groups, calculated to limit the freedom of science or the research upon which it is founded. Throughout the discussion of an accelerated, state-supported research, there has been ample freedom for participation by all interested persons from government, industry, and the universities. Representatives of the association of scientific workers also took an important part in all discussions. And most important to an orderly consideration of the subject, in Nature there was a vehicle for prompt and impartial presentation of the various opinions.

A study of the extended discussion relating to the expansion of research leaves the clear impression that Britain will develop sound plans for a wide use of science in the future, directed both to national security and the welfare of the peoples of the Empire.

The situation as to the development of science in Russia is not so completely known. The general control of research is vested in the Academy of Sciences, which directs the efforts of thousands of research men in all quarters of the Soviet Union. Through its close relations

with the universities, the Academy also has the selection of the more promising science students. With the great expansion of universities and the much larger number of students enrolled in the science departments, the research personnel of the Soviet Union is increasing on an incredible scale, probably far ahead of any other nation. The Soviet Union has shown consistent good judgment in dealing with all phases of science. Research is a respected profession with a promising career for capable students. It is publicized widely in the daily press and scientists become national figures. During the war, Russia consistently maintained research on a high plane, and refused to sacrifice scientists on the war front. Construction of laboratories and research institutes has proceeded steadily so that at the present time research facilities in the U. S. S. R. are probably second to none, either as to number or equipment. Most important to the conservation of the time of research leaders, these laboratories are well staffed with assistants. At the same time field expeditions on a lavish scale have been continued, thus adding to a knowledge of natural resources. If there is a difference in science as practiced in Russia, it is probably that science there is more clearly directed to a purpose.

Further expansion of state-supported science poses no problem for Russia. The machinery for directing additional research now exists, and laboratories and universities with adequate staffs are available. Science will certainly continue to expand, for the leaders apparently realize that an adequate standard of living involves the use of science in the development of natural resources, in the growth of industry and commerce, and in further research in matters relating especially to health, food, and housing.

Elsewhere in Europe there are numerous signs that a centralized and expanded science will develop in the near future. Scientists met the most discouraging adversity in the war years with courage and devotion and kept alive a distinguished research tradition. With the record of those war years, it requires little imagination to anticipate a steady and strong growth, possibly even a great increase in research throughout Europe.

With science taking giant strides in other countries, the question might well be asked, "What of America?" There is need now to take stock of our place in world science, for isolation in science is even less possible than is political isolation. As we review our own place in science, there is room both for pride and humility. In the war we gave a crushing demonstration of the scientific and technological abilities and the industrial might of the United States. In accomplishing this miracle, however, we plundered our natural resources and we raided the ranks of our younger scientists. The net result is that we face a postwar world with depleted reserves both as to scientific personnel

and natural resources. The dearth of trained scientists is doubly serious, since the shortage touches teachers as well as research workers. Of these, the teacher shortage may be the most serious, for until the universities and technical colleges are staffed effectively we can never hope to make up the present deficit in scientists. When we consider the planned increase in science in other countries, it is obvious that the elimination of our present deficit in research personnel is only a first step toward our goal.

Leading scientists are agreed that our country must embark on an enlarged program for scientific research and development. They further agree that to accomplish this object and insure the security of the Nation and the welfare of its citizens, federally sponsored science is necessary. There is disagreement as to details touching the disciplines involved, the types of institutions which should participate, and the nature of the administration required. It seems certain that legislation dealing at least with some of the needs of research will be enacted.

The greatest source of danger to a plan for subsidized research is that the country as a whole does not truly appreciate the importance of this subject. With doubtful or wavering public support, a period of rigid economy might well cripple or completely stop such a program. This is a real danger, for science has always been the first casualty in periods of retrenchment. The continuity of such a program can be assured only when the people of this country know that it is certain to win over a long period—even more, when they realize that without a strong, efficiently administered program of research, we, as a nation, shall be competing at a great disadvantage in a new world. We shall be competing at a disadvantage not only as to national security and national welfare, but also in maintaining the world leadership we won in the period ending with the close of the war. Public support must be based on public appreciation of these facts, and only when this occurs will a program for increasing scientific investigation receive active and continuing support. The public should be treated with frankness; it should be informed that research is a gamble both as to the specific results obtained and the time involved. This is especially true in the case of basic research, the type most urgently in need of stimulation.

Is the world preparing to turn to competition in science, and what has happened to place science in the forefront of international affairs? Science and invention together had made an impressive record in the 40 years antedating the war. These developments touched the daily lives of millions. An enumeration of a few of the major industries will illustrate the great social implications of expanding science. In 1900 there were few telephones. The major growth of this huge utility falls within the 40 years under consideration. Within this same

period there came the automobile, airplane, motion pictures, rayon, and the radio. These inventions became the bases for giant industries, giving employment to millions, paying huge taxes, and providing conveniences that, while now commonplace, have had social influences too great to assess. Most of us knew of these achievements, but it took the greatest war in history to crystallize this knowledge into a full appreciation of science.

We shall consider science as related to national security only long enough to admit that we must have adequate research on weapons related both to offense and defense. To plan otherwise in our present confused world would be unthinkable. Preparedness, more than ever before, is the price of liberty. We may well remind ourselves that national security, for the long pull, should be based on something more lasting, and less exhausting, than more and bigger ships, planes, bombs, and guns. It would be well to be warned by the numerous examples in history that give weight to the words of Nietzsche, "simply by being compelled to keep constantly on his guard, a man may grow so weak as to be unable any longer to defend himself." In planning means of avoiding future wars we must remember that in human contacts, whether on individual or national levels, fear is a poor substitute for understanding and reason.

Our principal consideration will be given to research aimed at improving the welfare of our people. This includes the types of research concerned with the development of the country's resources, its agriculture, industry, and commerce. As a nation can be only as strong as its individual citizens, the research program must be directed also toward the health of individuals, their food, shelter, and clothing. Since our goal is the accumulation of new knowledge on a wide front, all promising sources of information should be enlisted. It is not a small program, for its orderly development means the utilization of both basic and applied research in many disciplines, including not only those of interest and utility to man, but also those dealing with man himself and his relations to other men. It means the cooperation of institutions of many types, the universities to train scientists, and to conduct basic research; private institutions to undertake investigations in all categories and in all fields; Federal agencies to conduct both basic and applied research of wide scope; and finally, participation by the magnificent research services of American industry. The task ahead calls for the greatest wisdom that can be brought to bear upon it. It is a challenge to the Government and to the scientist alike. There must be cooperation between agencies, for from these contacts there will arise the encouragement and inspiration so necessary to creative achievement. Perhaps I should say cooperation and coordination; but since the latter term is susceptible of several definitions,

especially as to degree, it should be used with care. A reasonable amount of coordination is required to make certain that the new program of research will become a useful and effective portion of the Nation's total research. Care must be taken, however, to see that this program does not become a super science department with power over all national research. In the interest of good administration, the authority to direct and the responsibility for results must be bracketed together. Beyond this, there is required the application of a few general principles that have been demonstrated to be necessary to any efficient conduct of research. Science cannot be regimented. At most it can be directed only along very broad lines, for who can declare in advance what is of great and what of little importance? It is obvious that specific direction could never have developed a Pasteur or a Kekulé. Their contributions to science arose from their own inquiring minds, from a great body of knowledge they had accumulated, and from disciplined imaginations. Under close supervision they would have been superior investigators, but they would probably be forgotten now. The degree of supervision and planning must be determined by a body of men who understand science and appreciate the difficulties of research, men who are capable of judging progress and the ability of individuals without looking over a worker's shoulder or, even worse, requiring multiple reports. Accomplishment has been observed over the centuries, and, while it is susceptible of broad variations, its recognition by experts does not require a lifetime. The selection of wise administrators of research, the determination of when and how to provide support, and how much to provide will always hold the key to success in any expansion of the research of the Nation. Funds can be provided by law, projects can be assigned, but this alone cannot assure maximum results, for organization cannot do what only the genius of individuals can accomplish. The statement of Plato, that "under the influence either of poverty or of wealth, workmen and their work are equally liable to degenerate," is as true now as it was in his day. We must have understanding of science rather than science worship, and above all we must realize that science is a working tool, a means to an end. In stressing the use of research for social ends we are only restating the ideal of Benjamin Franklin, who made that objective a basic purpose of the American Philosophical Society.

The Federal Government is now engaged in research on many matters that concern both the individual and the Nation as a whole. The development of national resources and their wise conservation constitute a field in which the Government should lead and cooperate with all others engaged in similar research. This relates to forestry, geology, and agriculture in all phases, to mention a few of those close to national well-being.

Agriculture has always been closely related to human progress and still plays a dominant role in man's health, food, and clothing. With industry it will to a great extent determine his standard of living. Though plenty and peace may not be invariable companions, when the life of individuals is not a hopeless struggle for existence, class strife within a nation and hostilities between nations certainly tend to disappear. A greater knowledge of agriculture will bring us nearer to this objective. There is still much to be learned about the land and its maintenance, about crops and the economics of farming. We must learn well and rapidly, for our new lands are shrinking. Our last large frontier is in the Arctic, and we are far from a knowledge of how to utilize it. In these basic matters that affect all citizens the Government should be the leader and coordinator of research, with responsibility for its effectiveness and its extent.

The role of research in solving many of the problems of nations seems to be well established, and the welfare of a nation in this industrial age depends very largely on the continuing extension of the horizons of knowledge and the practical application of that added knowledge. The obvious question relates to how this may be brought about in this country without incurring excessive expenditures and thus jeopardizing the success of the entire program. It seems clear that the project is of such scope and size that it must be administered and subsidized at the national level. The direction of such a complex program must be in the hands of experienced men who understand science and appreciate its social implications. Wide representation on such a group is necessary from all the agencies contributing in an important measure to the success of the program. This would include the Federal service, universities, private nonprofit research organizations, and industry. This group provided with advice from committees representing the various disciplines and with administrators as required would be fully capable of selecting broad fields for research, of selecting individuals or agencies to conduct research, and of determining the amount and nature of support required.

The types of national science foundations thus far suggested are of less importance than the abilities of the men appointed to the foundation. If the leaders are chosen for their qualifications, their distinction, and their ability and desire to serve, the administration is in safe hands. The tendency toward honorary or part-time appointment can be overdone. The program is too large, too complex, and much too important to be administered as an avocation.

It is not to be expected that such an organization could operate at full speed immediately for it must learn as it proceeds. It could, however, undertake several objectives with full knowledge that it is on the right track. One of these relates to providing additional research

men, in part to make up the acute shortage which developed during the war, and partly to assure a supply of well-equipped men to carry forward the increased research this country must undertake.

One of the first steps to be taken in increasing trained research personnel is to eliminate much of the wastage of promising students who for financial reasons fall by the wayside before completing their academic training. The salvage of superior students from this group is an efficient and economical plan, for they have completed part of their training and their capabilities are already known. Scholarships should be awarded only to those who can profit from university training, and the leaders among the students should be educated just so far as this education is of use to them and to society. Those chosen to seek further knowledge should meet the high qualifications established by James B. Conant.

For the scholar, the seeker after truth, whether he be mathematician, archeologist, scientist, philosopher, poet, or theologian, must come into the court of public opinion not only with clean hands but with a consecrated heart. He must have integrity of purpose, a disciplined imagination, and the power of critical analysis of both the problem at hand and his own contributions. In addition, he must have high standards of performance as to the technical aspects of his task.

In granting scholarships it would seem wise to examine present organizations experienced in this field to learn whether the existing machinery or methods for this purpose are capable of administering a larger Government-sponsored scholarship program. It would be wasteful to ignore demonstrated accomplishment in this specialized field.

In training young scientists it must be borne in mind that quantity can never take the place of quality. New ideas, or new applications of old ideas, do not arise from oceans of minds. They come from a few superior minds in which inquiry, knowledge, and imagination are compounded in favorable proportions. Linnaeus long ago noted that encouragement should be given to clever students, "for the great discoverers are among them, as comets among the stars." The effectiveness of a training program depends almost entirely on the ability of the teachers, as has been so often demonstrated where a single preeminent professor has carried his department to first rank within the nation. If outstanding students are to be aided in obtaining the training necessary to speed research at full efficiency, it is equally important to relieve the outstanding teachers of the extraneous duties which reduce their use as teachers. It may even be said to be more important, for a single teacher may train and inspire many discoverers. In any training program it is thus necessary to seek both students and teachers. Once these are brought together in an environment favorable to science, it will be demonstrated that huge numbers of investigators are not required to keep our country among the world leaders in science.

Under the scholarship program the nation will become deeply involved in educational matters, and it cannot escape a direct interest in the quality of training facilities. During the war period, colleges and universities gave close study to their curricula with the idea of making improvements where changes were indicated. One change suggested was a broader base in training in the first college years. The report of the president of Pomona College to the alumni illustrates how one college has met the changing trend: "The new curriculum is dominated by the philosophy that in the first 2 years the student should acquire certain fundamental skills, appreciations, and bodies of knowledge." This is a definite change in the right direction and agrees closely with British statements on the subject. Broad training in fundamentals will provide the student with the confidence and the working tools so necessary to systematic solution of problems.

Another urgent field for expanding our educational facilities is the training of specialists in foreign areas. The need for this has been expressed very well in the constitution of the United Nations Educational, Scientific, and Cultural Organization: "Ignorance of each other's ways and lives has been a common cause, throughout the history of mankind, of that suspicion and mistrust between the peoples of the world through which their differences have all too often broken into war." The war showed us that area experts in the United States were almost nonexistent. Through the cooperation of the universities and colleges great strides were made to meet the need for such knowledge. Training in this field must be continued since the necessity for such experts will not be less with the coming of the peace. We must learn more of other peoples and their problems, for whether we like it or not we are now neighbor to all peoples of the world.

Interdisciplinary training should also be stressed. A research man should have knowledge of several disciplines beyond the specific knowledge of the division or subdivision of his own field of science. With this added equipment he has a clearer understanding of his problems and possesses abilities to use these related disciplines for their solution. He is not only a better research man on his own, but with this wider appreciation of the utility of other disciplines he is more valuable as a part of a research team. War research demonstrated that scientists often received their most useful assistance from co-workers, who brought to the solution of problems viewpoints and methods from widely different types of work.

The continuing success of the plan to stimulate research will depend to a large extent on the understanding and intelligence used in the administration of the program. Its first concern is to outline policy, to determine what funds are to be procured, and to learn how to obtain the maximum of results from the funds at hand. The latter considera-

tion includes a decision as to the approximate proportion of the funds to be expended for security research and how and where it will be used. The remaining portion for welfare research must be further divided between scholarships and basic and applied research. As to agencies, it must be divided among university laboratories and classrooms, private, nonprofit research institutions, Government research laboratories, whether Federal or State, and laboratories for the solution of industrial problems. The selection of laboratories and men, the terms under which funds will be available, and the approval of projects will all have much to do with the degree of success of the undertaking. Administration of the program will require the continuing study and advice of many scientists from all disciplines. Projects may or may not succeed, but they should have an honest chance by being placed in the friendly surroundings of skilled investigators and well-equipped laboratories. Beyond this each project should have a fair test as to time. Year-to-year allotments with no assurance against reduction or termination are not likely to attract the best minds. Utilization of our leading scientists for stop-gap experimentation would be unfair both to the men and to the Nation. No practice should be adopted as adequate until its soundness has been demonstrated. One example will suffice. We speak of basic and applied research as two separate fields, which must be kept distinct. Some believe that the basic research workers would be unable to apply their findings to practical use and that applied research workers would be of little use for fundamental research. This may hold for a small number of scientists, but a large number of men have shown by their work during the war that the same general qualities are required for superior research of either type. Basic and applied research are now used together by the London, Midland, & Scottish Railroad under a plan by which research men from the railroad and its cooperating universities are exchanged for temporary periods. From preliminary observations it seems that both basic and applied research will profit from this arrangement. It is a further step in breaking down the cell walls that have, in varying degrees, insulated one worker and one problem from another.

Those who will be responsible for the administration of public-sponsored research must expect criticism, for they are using funds in which everyone has vested rights. Public support is absolutely essential to the continuing success of an accelerated program; and this support to be lasting must be based on an understanding of the aims of the program and an appreciation of what science has done and can do again. There should be full publicity on all phases of the operation of the program. It must be necessary not only to be independent of the influence of pressure groups but also to be able to prove that

independence. Though wartime science went from one triumph to another, it must be remembered that peacetime research will be measured by different criteria. During the war the cooperation of research men was a patriotic duty, and the cost of projects was entirely secondary to speed and to success in solving problems. In times of peace the cost of research programs will become a matter of major importance and one for annual discussion.

The results of research touching individual or national well-being should be given the widest distribution. This should be the standard method not only of diffusing useful knowledge but also of reporting progress. Used intelligently, it will make unnecessary the collection of multiple reports, questionnaires, forms, and records, which at best accomplish little more than to delay the work and drive out those investigators who prefer research to the piecemeal discussion of it. Publication of results should be prompt and full, and adequate distribution should be made nationally and internationally. This will serve not only to speed research but also to prevent needless duplication of effort.

Whether publication should be undertaken in more than one language is problematical. I should incline to advocate that each nation publish in its own language and leave to an international catalog and abstracting service the task of furnishing abstracts and serving as a clearinghouse for providing translations in such languages as may be requested. This would be no great change from the International Catalogue of Scientific Literature, which, after years of effective service to science, suffered so grievously from the first World War that it never recovered. If the nations truly wish to cooperate, let them resurrect this useful service with such changes as the needs of the present day may require.

Although our discussion has been concerned largely with the national aspects of such a research program, there are many who will regard it as only one part of a larger problem. The real objective of this undertaking for the increased use of science depends largely on who happens to be explaining its purpose. To one, science may insure national security; to another, it may mean the economic welfare of the nation; while a third might look at the world and see international cooperation and understanding and enduring peace. Science utilized more widely can raise the standard of living in America, it can provide jobs, it can turn the wheels of industry and fill ships with exports. It can increase the comforts of individuals; and, as far as weapons may be concerned, it will certainly increase the security of our Nation. All this, however, is the answer to only a part of the question as it affects Americans. Our welfare over any long period is related to the welfare of other peoples, for now as never before poverty and misery in one part of the world affect the prosperity and well-being in all parts

of the world. Thus our standard of living cannot be completely and permanently independent of that of other peoples.

As a preliminary to improving the economic status of peoples it is urgent to speed the work of recovery in all countries. This heavy task calls for international cooperation in all fields of science. Obviously those nations that have suffered the least must assume the leadership in this program of restoration. The question as to where this cooperation should start or what it should undertake is one of some magnitude. The most urgent need is in those countries that were overrun by the Axis, in which science was destroyed in part and scattered. The first step is to help each nation to help itself by organizing exchanges of current literature, abstracts, and translations as rapidly as possible and to bring victims of a scientific black-out up to date on recent world research. Restoration of the scientific literature in war-area libraries is a large task, but an early beginning should be made. Contacts between workers on similar problems should be established and assistance given, if only advisory, on research materials, equipment, and other facilities. International contacts and meetings concerned with science should be expedited and the exchange of students and teachers promoted. The preliminary operations in these fields are largely multilateral in nature and they should fall within the scope of international organizations. Of these the one covering the broadest field is the newly formed UNESCO; and there are others of lesser scope, some of which are ready for operation. It is too early to make promises as to the activities of UNESCO, for it is still in the preliminary stage of organization. Specific programs have been proposed covering such subjects as the social problems of housing, language teaching, and surveys for rehabilitation of the educational systems in devastated countries. It will undoubtedly serve on a world-wide basis to promote the free flow of information, both cultural and scientific, and to encourage the exchange of students, teachers, scientists, and artists. It will be a general source of information to facilitate giving to nations the educational, scientific, and cultural aids lost in the war. In undertaking these activities, however, the projected aid is on an advisory rather than on an active participating level.

The more active operating programs in international cooperation will include those on a bilateral basis. Such projects, arranged through the Committee for Scientific and Cultural Cooperation, are already in operation in many places in this hemisphere. Projects of this type, now active, include such diverse fields as agriculture, anthropology, geology, tidal studies, vital statistics, and meteorology. There is included also cultural cooperation in many fields of the humanities and the exchange of personnel, including scientists. These projects, which must be of value to both participants, are operated on the level of the people, and active participation by both countries is required. The

objective of the program is to further understanding between the nations and peoples of this hemisphere, to advance their interests, and to maintain peace. That the plan is successful in advancing international relations has been demonstrated repeatedly. Authorization for the extension of this program to other parts of the globe is now before Congress. Cooperation in science on a world-wide scale, in improving economic conditions within nations, can contribute much toward removing a fertile and continuing cause of wars. We must remember that any discussion relating to the welfare of peoples cannot avoid consideration of ways and means for preventing wars, which cause losses in human and material resources beyond appraisal. The last war cost this country alone over a million casualties and 354 billions of dollars. These partial costs show clearly the futility of planning a comfortable standard of living if wars, on the modern scale, are permitted to recur at intervals.

The question has been asked as to whether science is not given an undue portion of the projected program and whether the well-being of peoples would not be advanced further by including the humanities. These have always been international in character and thus furnish a meeting ground on which races, creeds, and nations may find common appreciation and understanding. The humanities play an important part in the progress of mankind, and obviously the advancement of human welfare and peace must include the humanities in ever-increasing amounts. One answer to this question is that a program including the humanities is now operating under the guidance of our State Department and it will expand as it receives further support from the United Nations Organization and from other programs of international scope. It is a separate program and should remain so, both as to direction and support. Perhaps the principal answer to the question is that survival and recovery are the immediate needs, and science has demonstrated its ability to function in emergencies. Science is ready to go ahead now and it has world-wide support. In addition to meeting immediate needs, science can do much to sponsor international good will for it, too, is truly international in character. Science has an important role in pointing the way to the recovery, well-being, and peace of the world; but it will make its greatest contribution to human welfare when it realizes the necessity for pooling its efforts with those from other sources of assistance. Thus, whether we consider our problem from the national or world-wide viewpoint, all science might well adopt the ideal to which Hugh Taylor, in speaking for the physical sciences, gave such eloquent expression:

In the free world to which we still dare to look forward, with the soldiers and statesmen, artists, humanists, philosophers, and priests, we must integrate our scientific skills with the social and spiritual aspects of human life and nature. That goal attained, we shall not lack either direction or support.

TOWARD A NEW GENERATION OF SCIENTISTS¹

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Anyone who has had the good fortune to have lived many years in close contact with scientists of the first rank, and thus had opportunity to observe their methods, witness their achievements, and follow the results of their research, through engineering development and production, out into use by the public, cannot fail to realize the enormous value of scientific research.

To mention but a few outstanding examples of its value to industry, and of its even greater value to the public: Our laboratory researches on lamps and alloys have been major factors in reducing the cost of light to one-twentieth of its cost 45 years ago; X-ray practice has been transformed from a tricky, dangerous art of limited scope to a safe and exact science of the widest utility, with the saving of countless lives and untold suffering; and the electronic tube has been developed from an unreliable and feeble device to become the sturdy cornerstone of the great new industry, broadcasting, bringing employment to tens of thousands, and entertainment and instruction to millions.

For a person who has not had such intimate association with scientific activities, and hence has been less conscious of their achievements, it took this great war, with its diverse and spectacular scientific and technological accomplishments, to bring a realization of the potentialities of research. The life-saving miracles of blood plasma, penicillin, and DDT; the marvelous extension of the range of vision given by radar, with its immunity to fog, cloud, and darkness; the automatic bomb sights, computers, and gun controls which made our bombers and fighters so deadly; the enormous speed with which the greatest and most efficient navy the world has ever seen rose from the flames of Pearl Harbor; the great submarine pipeline which spanned the British Channel to carry the motive power to Eisenhower's armor for the swift dash from Normandy to the Siegfried line; these and

¹ Article based on an address of welcome to a group of high school science teachers taking, at Union College, Schenectady, N. Y., a special 6 weeks' course in modern physics, made possible by General Electric Science Fellowships for Teachers. Reprinted by permission from the General Electric Review, vol. 48, No. 8, August 1945.

many other technical triumphs have awakened the public to the limitless potentialities of research and technology.

ENORMOUS EXPANSION OF AMERICAN WARTIME RESEARCH

Much of American industry learned its lesson in the First World War, when it found, as a result of the British blockade, how dependent it had become on German laboratories for many essential materials and supplies. In consequence, industrial research laboratories in this country multiplied many times over after the war, with great advantage to our peacetime economy and with invaluable results when a Second World War again caught us unprepared.

This war is much more mechanized than any which has preceded it, so that the demands and opportunities for scientific and technological developments have far surpassed anything in history. Thanks to the successful mobilization of the Nation's scientists and engineers, the demands have been met and the opportunities fully grasped, so that in almost every respect our armed forces were before long equipped with more effective weapons and armament than those of our enemies, despite their long head start in military preparations. Marvelous as has been the achievement of American industry in conversion, almost over night, from peacetime manufacture to the production of munitions of all kinds, in quantity far exceeding anything that the world had ever seen, or that even Hitler had dreamed of, no less marvelous has been the swift conversion of our Nation's science and technology from peacetime projects to the staggering task of overtaking and surpassing the German scientists and engineers who had been devoting years to the objective of building up an irresistible war machine.

That formidable task for the most part has been successfully accomplished, and although much of what has been done is still kept secret, enough has been published to give the American public a realization of the magnitude and diversity of scientific achievement in this most mechanized of all wars.

SUSTAINED RESEARCH EFFORT REQUIRED

From this conception of our potentialities has arisen a demand that the coming of victory shall see no slackening of intensive scientific research, but on the contrary, shall see the conversion of research, in full strength and intensive effort, to the promotion of our peacetime economy. Public and politicians alike are looking to research to develop new and better products, to create new industries, to prevent unemployment, to insure permanent prosperity for all, and to raise to new heights our Nation's standard of living.

Those hopes, although often too rosy, will insure much greater financial support for research, both governmental and private, than

has ever been available before. How far those hopes will be realized, or how far they will be disappointed, will depend on the quantity and quality of available research workers. More will be needed than ever before, and not every boy or girl has the aptitudes needed for successful research. Those aptitudes must be sought for, and, when discovered, encouraged and developed, if the nation's research needs—the needs of industry, of governmental laboratories, of medical institutions, of universities—are to be met. That is the all-important task which faces the science teachers of our high schools. That is why any heightening of your efficiency may produce unforeseeable benefits to our nation's welfare. That is why this program will have potentialities for good, greatly exceeding its immediate benefit to you.

NEED FOR PUBLIC UNDERSTANDING OF RESEARCH

In spite of the prevalent enthusiasm for scientific research, there are some who have strange ideas of its nature. There are some who might read into my foregoing remarks the purely materialistic desire that as many adaptable children as possible should be shaped into little cogs to fit the industrial machine. Of course a conception of industrial research which would class a Whitney, Coolidge, or Langmuir as a cog is absurd, but no more absurd than the dictum gravely pronounced from the bench of a Federal court that industrial research may involve no more than finding a needle in a haystack by the simple process of dividing the haystack into a large number of small segments and then hiring an equal number of hands to paw through their respective segments. Such a misconception would be too abysmal to deserve notice, were not this court in a position to affect profoundly the patent laws and consequently the technology of our nation; but I have cited it because it reveals the same ignorance of the intellectual process involved in scientific work that is shown by those who deplore the spread of science teaching in our schools as an encroachment on the cultural studies.

By cultural studies are usually meant literature, history, and foreign languages, which for generations have stood as the pillars of our school curricula, based on the initial mastery of the three R's. It is not our intention to minimize the cultural value of those stand-bys. Literature and history especially are essential ingredients of any culture. However, it must be insisted that in these times science should and must take its place beside them with full parity as an essential to culture.

J. W. N. Sullivan has written in his book, *Limitations of Science*, that, "Science * * * is now the dominant intellectual interest of mankind." Can a man be called truly cultured if he is ignorant of "the dominant intellectual interest of mankind"? The study of science

is the path which leads to contact with the greatest current thoughts and the most brilliant achievements of man.

Nor does that study lead only to a coldly impersonal intellectual stimulation. Properly approached, science presents aspects transcendently inspiring to the imagination and arousing emotion bordering on the sublime. Edward Fitzgerald, himself a poet who, in the Rubaiyat of Omar Khayyam has given us one of the masterpieces of our literature, has said, "Yes, as I often think, it is not the poetical imagination but science that every day more and more unrolls a greater epic than the Iliad." And another poet, Alfred Noyes, in *Watchers of the Sky* wrote—

Yet we, who are borne on one dark grain of dust
Around one indistinguishable spark
Of star-mist, lost in one lost feather of light,
Can, by the strength of our own thought, ascend
Through universe after universe; trace their growth
Through boundless time, their glory, their decay;
And, on the invisible road of law, more firm
Than granite, range through all their length and breadth,
Their height and depth, past, present and to come.
Year after year the slow sure records grow,
Awaiting their interpreter. They shall see it,
Our sons, in that far day, the swift, the strong,
The triumphing young-eyed runners with the torch.
No deep-set boundary-mark in Space or Time
Shall halt or daunt them. Who that once has seen
How truth leads on to truth, shall ever dare
To set a bound to knowledge?

For the acquisition of some knowledge and appreciation of man's greatest intellectual achievements, no other study can rank so high as science.

SCIENCE CREATES SOCIAL CHANGES

Science study is necessary also for a true understanding of the forces which are shaping our social and economic development. A. J. Balfour said more than 30 years ago.

Science is the great instrument of social change, all the greater because its object is not change but knowledge, and its silent appropriation of this dominant function, amid the din of political and religious strife, is the most vital of all the revolutions which have marked the development of modern civilization.

Should anyone think this an overstatement, let him consider the following facts. It is science and its applications that have so increased the productivity of agriculture as to abrogate the Malthusian law of growth of populations, transformed our economy from the purely agricultural to the largely industrial; provided the swift transportation, both horizontally and vertically, which has fostered

the concentration of population in our large cities with their towering skyscrapers; created our gigantic electrical networks, bringing cheap and convenient light, heat, and power into every workshop and nearly every home; enormously increased the output of labor, while greatly reducing human drudgery and shortening hours; raised the standard of living, until now the average man enjoys in his home such luxuries as no king could command a hundred years ago; annihilated time in communications between individuals and between nations; and brought such understanding of the marvelous mechanism of our bodies and of the ills that assail it that the average span of human life has been increased by a quarter century in a hundred years. On the other side of the ledger, these same advances have added to our social problems by salvaging countless numbers of the physically unfit and allowing them to reproduce their kind; have brought temporary but severe dislocations of industry and employment through the development of new materials, processes, and devices; and have multiplied many fold the horrors and devastation of war.

Surely no one should be called cultured who has no realization of the revolutionary changes produced by the tremendous impact of science on our civilization.

STUDY OF SCIENCE DEVELOPS HABIT OF OBJECTIVE THINKING

And science has a special value possessed by none of its associates in the school curriculum. It contributes to the most important function in education: it develops, as no other study does, clear and independent thinking.

Mathematics, it is true, calls upon and develops the reasoning powers, but its nature is essentially abstract. Bertrand Russell has said, "Mathematics may be defined as a subject in which we never know what we are talking about, nor whether what we are saying is true." I have known more than one man who was an expert mathematician but who was helpless in the face of a physical problem, until someone else bridged the gap by pointing out what physical principles were involved and how they applied, thus bringing the problem to the point where pure mathematical technique could be brought to bear. Still more helpless would he have been, had it been necessary to determine by experiment the nature and mode of application of the principles involved.

Mathematics is a most essential tool for science, but mathematics divorced from scientific observation can tell us little about the world we live in.

It is the study of science, and that alone, which enables us to observe our surroundings clearly, to perceive their interrelations, and to derive valid and useful conclusions concerning them.

And finally, it is only through science study that we can acquire that most valuable of mental habits, the scientific approach. The merest beginner in science soon learns that preconceptions, personal bias, and wishful thinking have no place in the laboratory; that each problem must be approached with an open mind, subject to no influence but that of established fact. Could that approach be learned by the majority of men and maintained in the affairs of daily life, how many of our political and social problems would be solved, and how soon the demagogue and political sophist would disappear.

True it is, that we have seen some highly trained scientists guilty, in political or social issues, of the personal bias, wishful thinking, and even unreasoning passion, which are characteristic of the undisciplined mind. But may it not be that they learned the scientific approach too late in life for it to become a habit, so that it remained nothing more than an accomplishment, capable of practice in the quiet of a laboratory, but impotent in an atmosphere of controversy?

ESTABLISH SCIENTIFIC APPROACH IN YOUTH

It is early in life that our mental habits form, and that fact gives tremendous value to the acquisition of the scientific approach as early as possible in school days. Herbert Spencer, in his autobiography, ascribes whatever success he attained in philosophy to the habit, developed in him during childhood by his father, of questioning the reason for everything he saw. If the all-important mental process which we call the scientific approach is to become an integral habit of mind, rather than a limited accomplishment, it must be through science subjects in the school curriculum.

All children profit from science study in proportion to their mental ability. Only through science teaching can those with real aptitude for scientific work be discovered and started on the research careers urgently demanded by the national interest. Judged from the viewpoint of either the nation's welfare or the individual pupil's best advantage, the work of the science teachers in our schools is of the utmost importance.

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